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REPORT OF RESEARCH AND RESEARCH NEEDS ON WATER QUALITY PROBLEMS IN THE STATE OF HAWAII

Edward F. Eldridge

Public Health Service
Portland, Oregon

June 1963

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REPORT OF RESEARCH AND RESEARCH NEEDS
ON
WATER QUALITY PROBLEMS
IN
THE STATE OF HAWAII

Edward F. Eldridge
Research and Technical Consultation Project

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Region IX

June, 1963

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REPORT OF RESEARCH AND RESEARCH NEEDS
ON WATER QUALITY PROBLEMS IN HAWAII
(A TRIP REPORT OF E. F. ELDRIDGE)
MARCH 12 TO APRIL 12, 1963

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FOREWORD

The over-all objective of the trip to Hawaii was to collect information by which to develop, in conjunction with the Hawaiian State Department of Health and others, recommendations for a program of research designed to provide the necessary knowledge to meet existing and potential problems of water pollution (water quality) of the Islands. This program is desirable in order that the research effort may be guided into objective channels and that the results may be usable for the future protection of the quality of the State's waters.

To appreciate the research requirements in the water quality and related fields requires an understanding of the unique conditions of climate, rainfall, land and its topography, soils, population and industrial development, economics, transportation, and the occurrence of fresh and salt water as they exist in this State. While many areas on the mainland of this country differ widely, none compares with those of the Islands of Hawaii. These unique conditions have their effects on the water quality situation, both existing and potential, and hence will influence the nature of the research program.

This report has been developed around four major items. They are:

1. A brief discussion of those characteristics which are unique to the Islands and which have an effect on the water quality problems.

2. An assessment of existing and potential water quality problems.

3. An inventory of the capacity of various research entities to do this type of research so far as facilities, equipment and personnel are concerned, and a list of projects presently under way or recently completed on subjects which appear to have a direct or indirect relation to the water quality problems.

4. A series of prospectuses, developed in some detail, of suggested research projects which appear to be required to meet existing and anticipated or potential problems.

ITEM I

LAND, CLIMATIC, ECONOMIC AND WATER CHARACTERISTICS

Many studies have been made and reports written regarding the characteristics of the Hawaiian Islands as they may affect the future of that State. These reports are, for the most part, available to those who have an interest in other areas of the State's development. For the purpose of this report, only those characteristics have been discussed which may in some way be related to the quality of the water resources of the Islands.

LAND

The State of Hawaii consists of eight islands - Kauai, Niihau, Oahu, Molokai, Lanai, Maui, Hawaii and Kahoolawe - which lie in the Pacific Ocean about 2100 miles southwest of San Francisco. (Figure 1). The total area of the State is 6,435 miles. Table I shows the area of each of the islands.

These islands are the result of volcanic action which has now ceased in all except Hawaii, the furthest south of the chain. All islands are mountainous and each is in a different stage of weathering. Kauai is the oldest and the most weathered while much of Hawaii is covered with comparatively recent lava flows in the initial stages of weathering. These natural processes have had their effect on the topography of the land, on the nature of the soils, and on the water resources.

Much of the land area of the Islands is rugged. Only a small amount, about 7.3 per cent, is adaptable for intense agricultural use. Urban development is largely confined to the coastal areas.

Soils, except those of many of the coastal areas, are composed of weathered lava and volcanic ash and are extremely permeable. This permeability of the soil and the porosity of the underlying lava results in high rates of water infiltration. The average rate is said to be about 6 inches per hour.

These soils in general are very reactive and are high in copper, cadmium, iron and manganese. Just how these factors, together with the high rate of percolation, may affect the quality of the ground water is not known. The statement was made, however, that some soils are sterile probably due to high concentrations of these minerals.

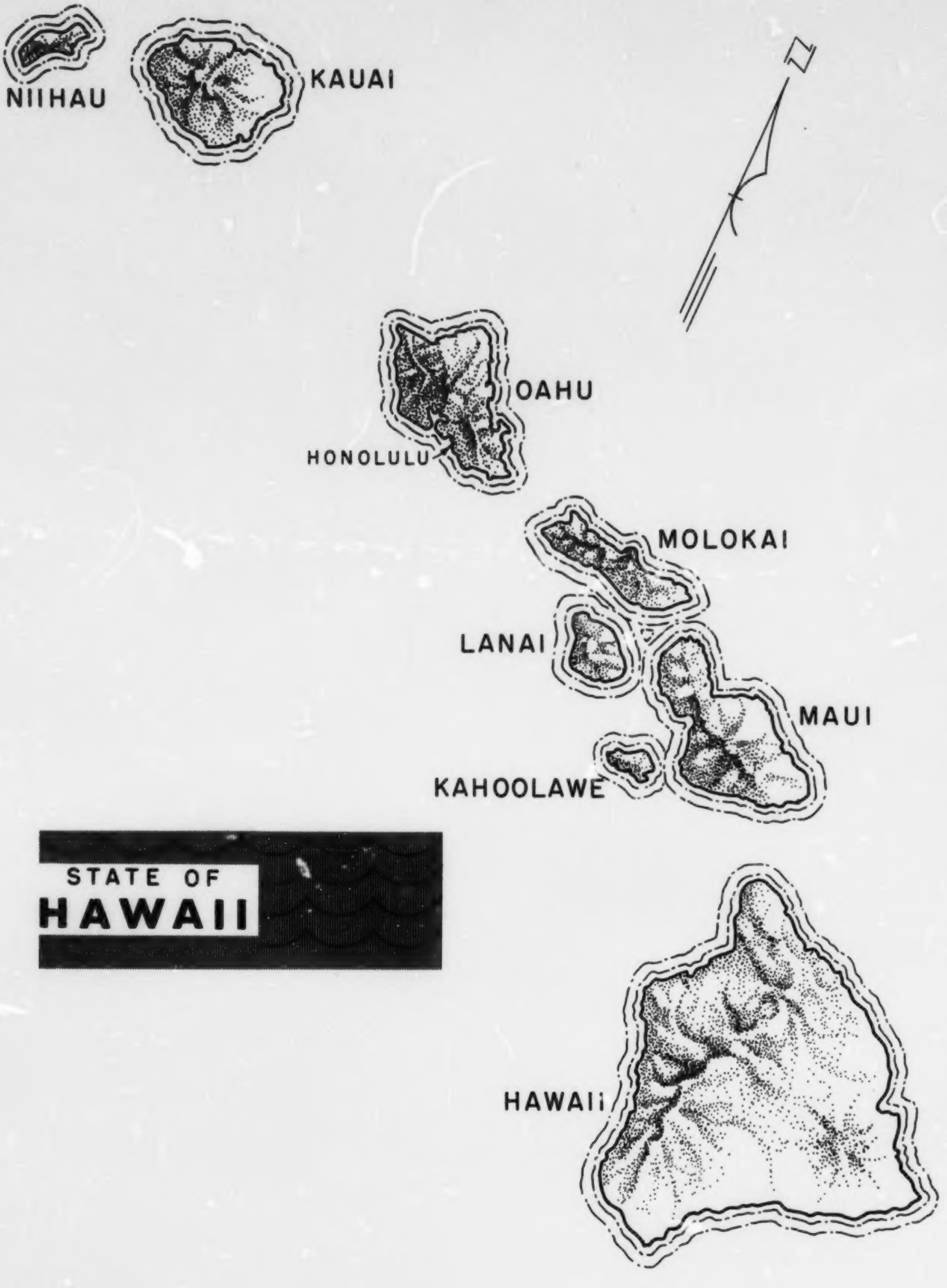

NIIHAU
KAUAI
OAHU
HONOLULU
MOLOKAI
LANAI
MAUI
KAHOOLAWE
STATE OF
HAWAII
HAWAII

Figure 1

Coastal soils in most areas are the result of the breakdown of coral deposits. These soils are much less permeable and are alkaline.

TABLE I

AREA OF HAWAIIAN ISLANDS

	Square Miles	Per Cent
Kauai	555	8.6
Niihau	72	1.1
Oahu	604	9.4
Molokai	260	4.0
Lanai	141	2.2
Maui	728	11.3
Hawaii	4,030	62.7
Kahoolawe	45	0.7
Total	6,435	100.0

LAND USE

The major uses of land are urban development, military reservation, agriculture, grazing and forest. The principal agricultural products are sugar cane, which occupies 342 square miles or 5.3 per cent of the total land area, and pineapple plantations which occupy 111 square miles or 1.7 per cent. Table II shows the land use of the various islands except Kahoolawe which is used entirely for military purposes. Several of these land uses may eventually have their effect on the quality of the ground water as will be indicated later in this report. Since it is believed that this is an important consideration, maps have been prepared of the five major islands, showing the locations of these land-use areas. (Figures 2, 3, 4, 5 and 6).

CLIMATE

Nowhere in the world is there such a wide difference in climate within short distances as in Hawaii. These differences are due to the size and location of the various islands and their mountains in relation to the prevailing winds. Rainfall and temperature in a local area are determined by elevation, the distance from the ocean, and its position on the windward or leeward side of the mountain ranges.

Temperatures are moderated by the trade winds which move across the islands in a southwesterly direction, and by the ocean which

TABLE II

LAND USE - HAWAIIAN ISLANDS
ACRES

	Kauai	Niihau	Oahu	Molokai	Maui	Lanai	Hawaii
Forest			116,999				
Grazing	119,000	46,000	42,879	100,000	168,000		1,040,000
Sugar cane	47,000		35,125		41,000		99,000
Pineapple	5,700		23,833	18,700	12,500	14,000	
Coffee							5,000
Macadamia nuts					270		2,080
Fruits & vegetables			13,094	50	1,070		1,400
Taro			149	30	70		150

"An Inventory of Available Information on Land Use in Hawaii," Vol. I. Economic Planning & Coordination Authority, Territory of Hawaii, January 1958.

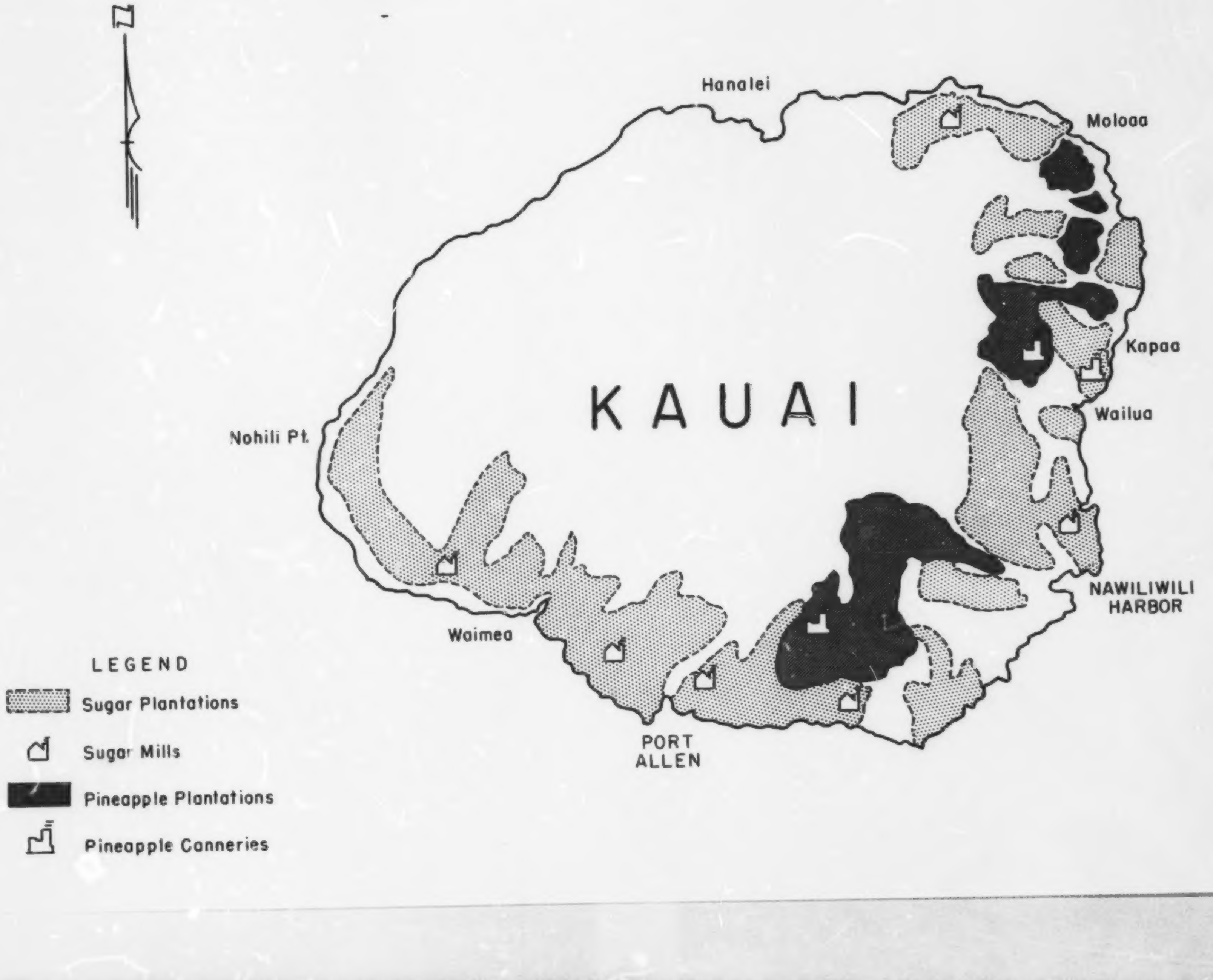
KAUAI
Hanalei
Moloaa
Kapaa
Wailua
NAWILIWILI HARBOR
PORT ALLEN
Waimea
Nohili Pt.
N
LEGEND
Sugar Plantations
Sugar Mills
Pineapple Plantations
Pineapple Canneries

Figure 2

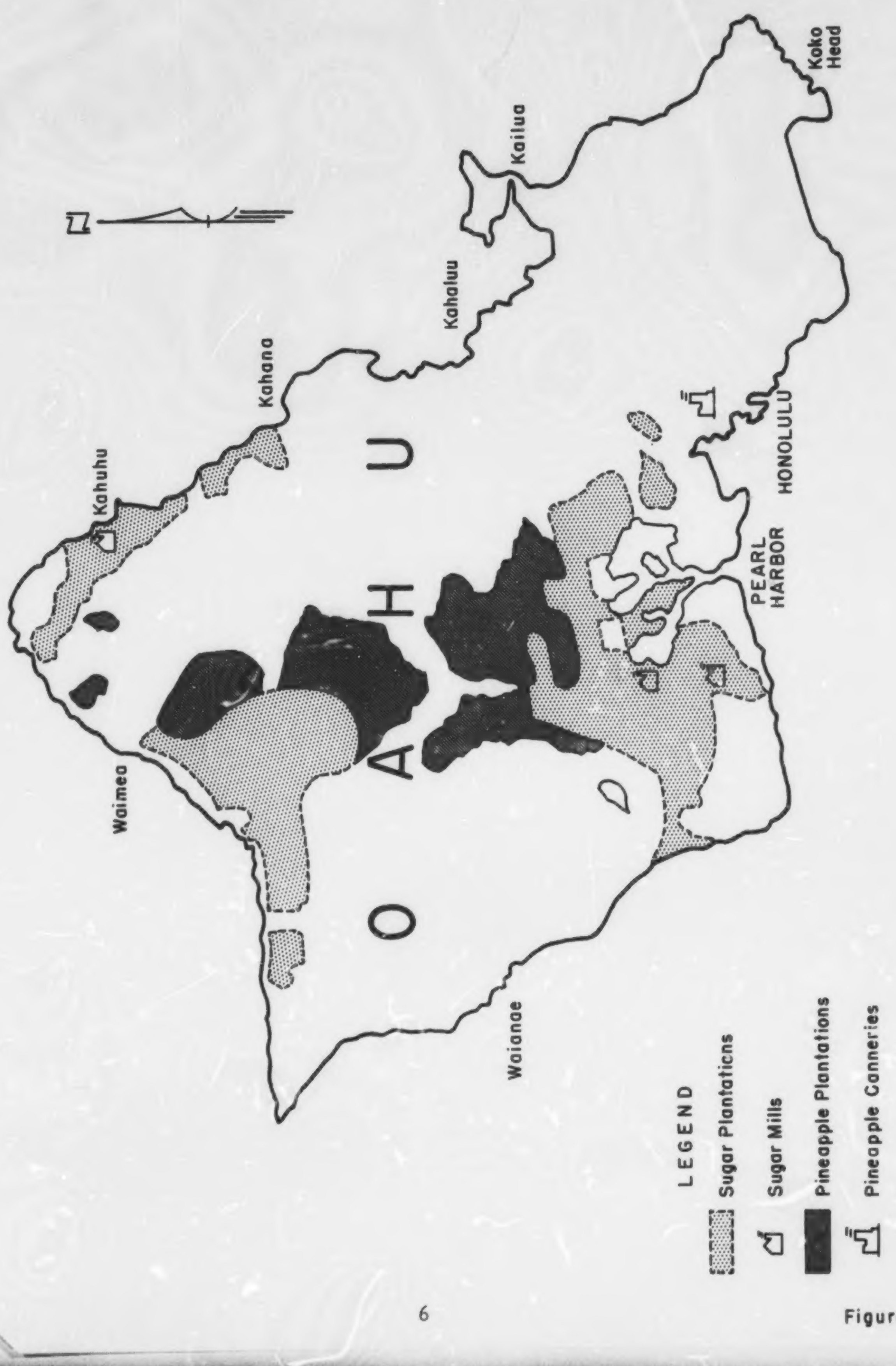

O A H U
Waimea
Kahuhu
Kahana
Kahaluu
Kailua
Koko Head
HONOLULU
PEARL HARBOR
Waianae
N
LEGEND
Sugar Plantations
Sugar Mills
Pineapple Plantations
Pineapple Canneries

Figure 3

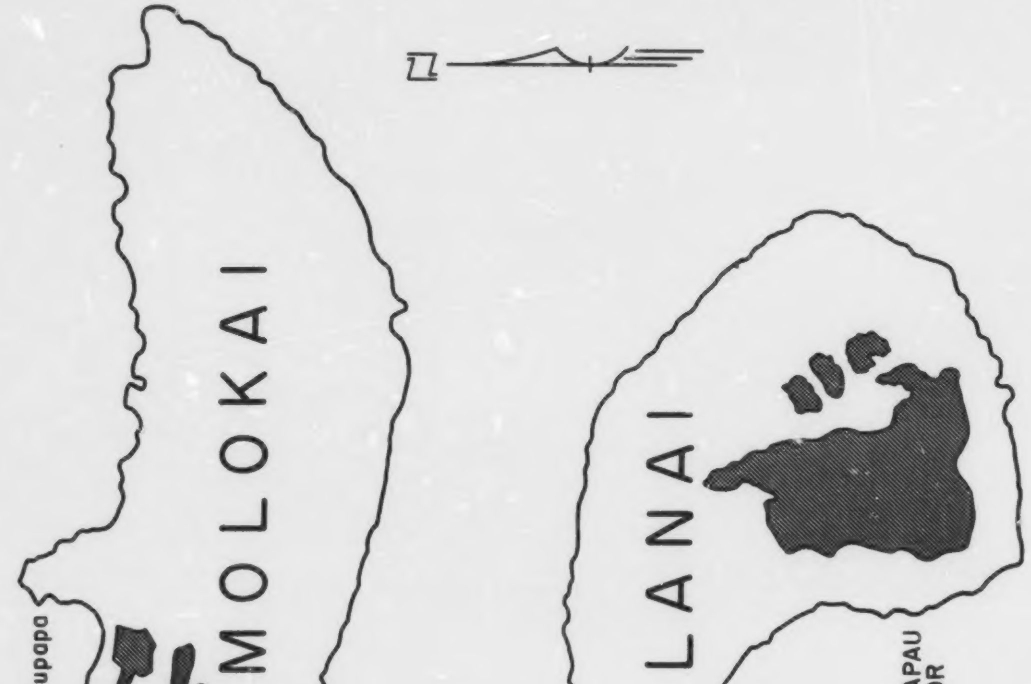

MOLOKAI
Kalaupapa
Kaunakakai
LANAI
KAUMALAPAU HARBOR
N
LEGEND
▨ Pineapple Plantations

Figure 4

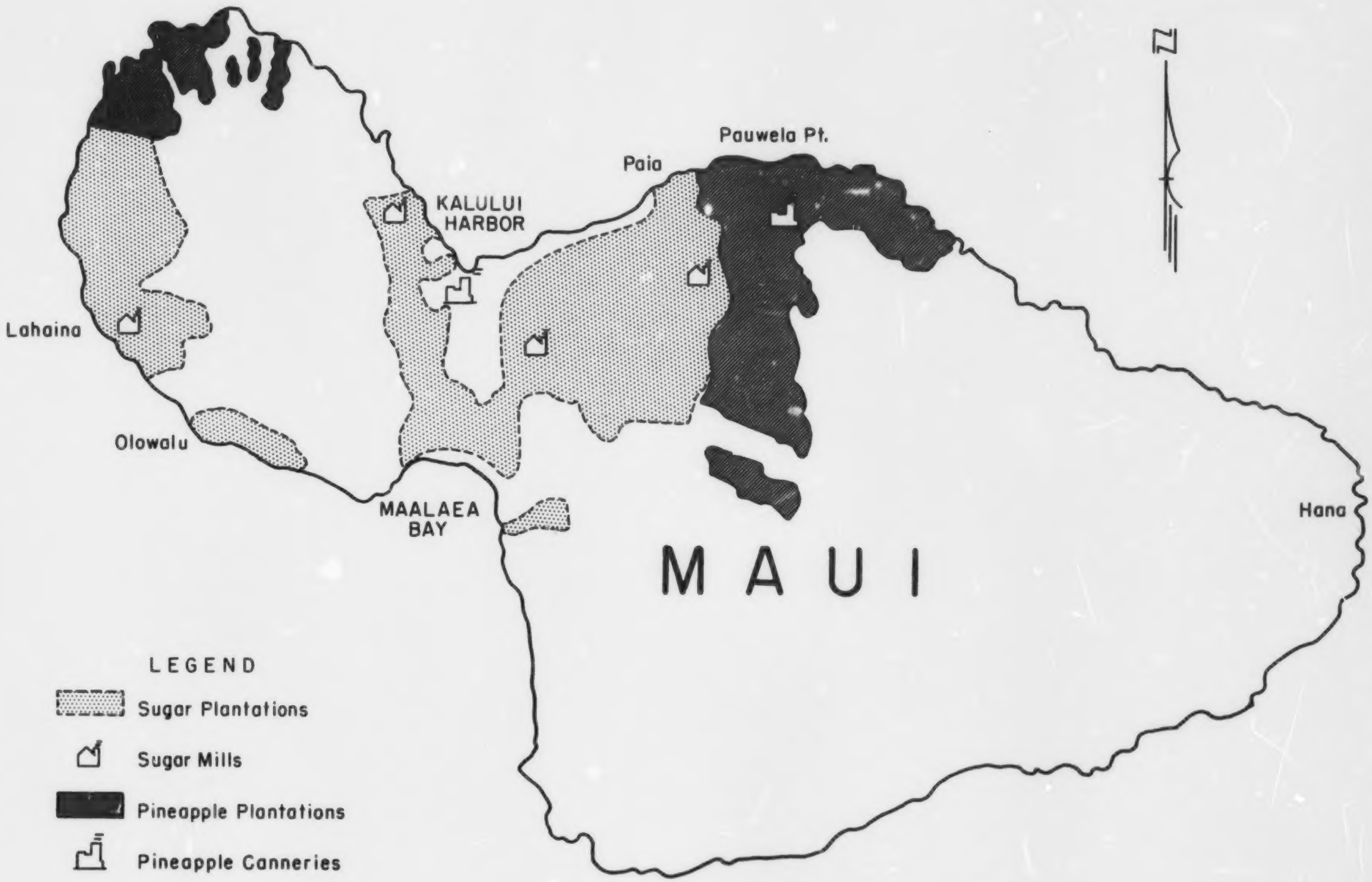

Lahaina
Olowalu
KALULUI
HARBOR
Paia
Pauwela Pt.
MAALAEA
BAY
Hana
MAUI
N
LEGEND
Sugar Plantations
Sugar Mills
Pineapple Plantations
Pineapple Canneries

Figure 5

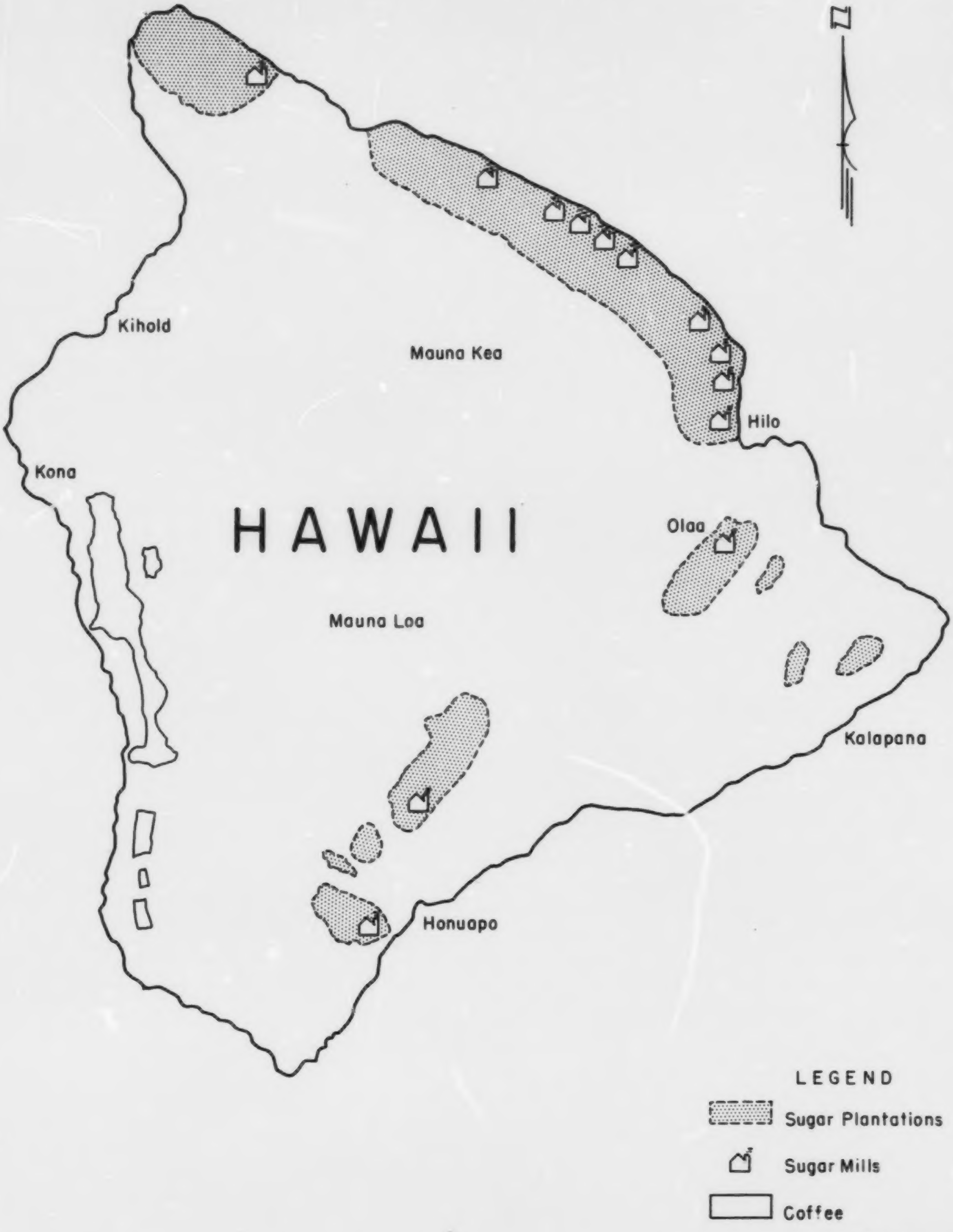

Kihold
Mauna Kea
Hilo
Kona
HAWAII
Olaa
Mauna Loa
Kalapana
Honuapo
LEGEND
Sugar Plantations
Sugar Mills
Coffee

Figure 6

surrounds them. The moisture-ladened trade winds are lifted by the mountains, causing high rainfall at the higher elevations and on the windward side. Under trade-wind conditions which normally occur over much of the year, the leeward sides of the islands are dry. The pattern is changed during short periods of the winter by south and southwest (Kona) winds which normally bring storms and hot humid weather.

Annual rainfall varies from less than 10 inches per year on the coast of the leeward side of several of the islands (Hawaii and Molokai) to over 400 inches on Mt. Waialeale on Kauai. The latter is claimed to be the wettest spot on earth. Since the rainfall pattern is a major factor influencing the water resources of the Islands, isohyetal lines showing average annual rainfall are shown in Figures 7 to 11 inclusive.

ECONOMICS

The Department of Business Research, Bank of Hawaii, in its annual Economic Report, covers in detail the factors involved in the economic growth of the State. A number of these factors will affect or are in some way related to the quality of the State's water resources.

Population Growth

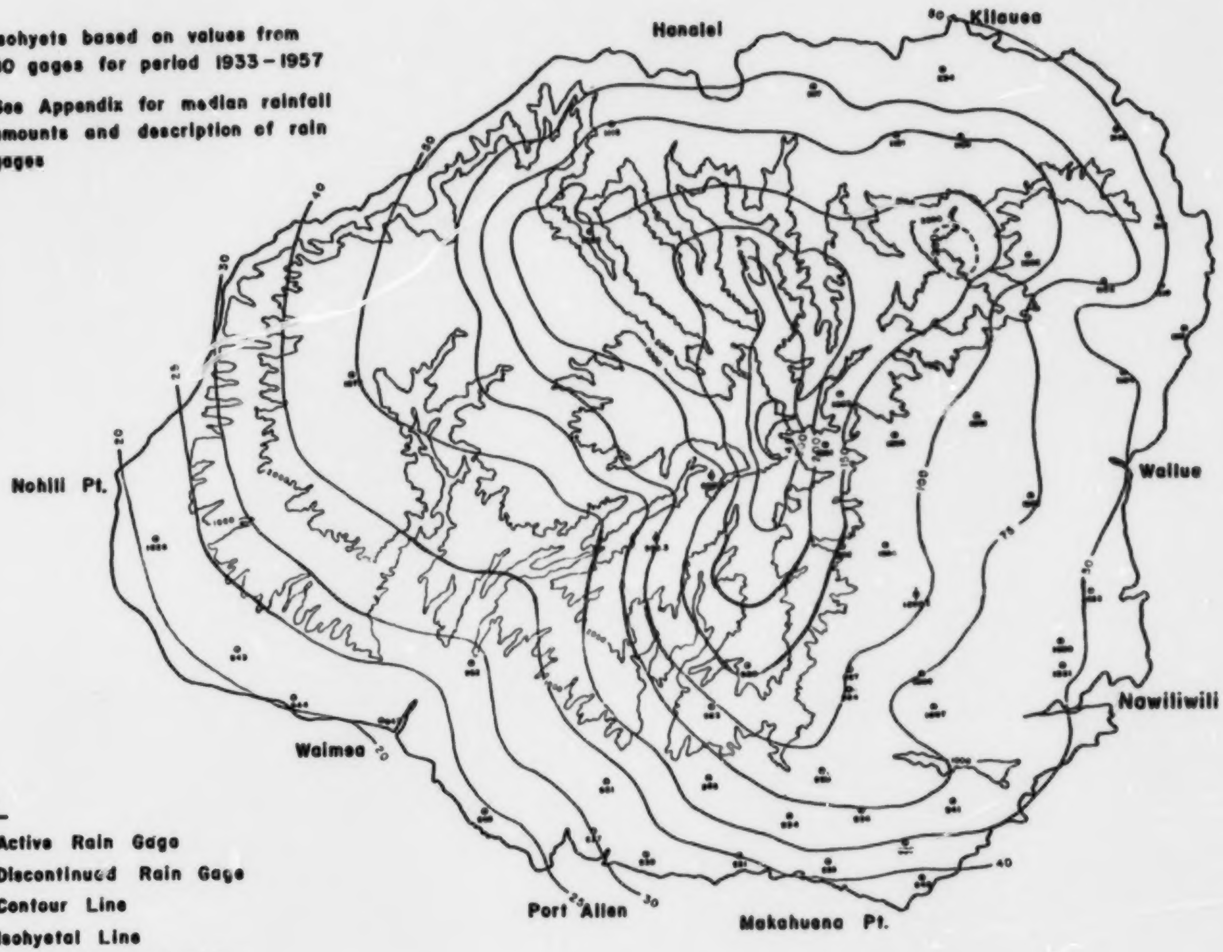
The population of the State as a whole has shown a steady increase over the past 50 years. The major portion of this increase, however, has occurred on the Island of Oahu and specifically in the Honolulu area. Many of the other islands have shown a decrease in population. Table III from the U. S. Census Reports shows the population trends for ten-year periods starting in 1910.

The downward trend on the islands except Oahu may change with an improvement in the transportation between islands. Presently the mode of transportation is by air and, while this system is excellent, it is costly and is limited to passengers. Freight and autos are moved largely by barge. There is an effort under way to develop a ferry system between the major islands which initially, at least, may need to be subsidized by the State.

Numerous studies and plans have been developed during recent years which may also influence the population trends. For instance, the Hawaii State Planning Office employed consultants to prepare a program for the development of "Visitor Destination Areas in Hawaii." This plan designates certain areas largely on the shorelines of the major islands for either private or governmental development as resort areas. Already large modern hotels have been built in such areas on Kauai, Maui and Hawaii. These may or may not be the result

NOTES: Isohyets based on values from 80 gages for period 1933 - 1957

See Appendix for median rainfall amounts and description of rain gages


Hanalei
Kilauea
Wailua
Nawiliwili
Makahuena Pt.
Port Allen
Waimea
Nohili Pt.
80
50
40
25
20
100
75
30
20

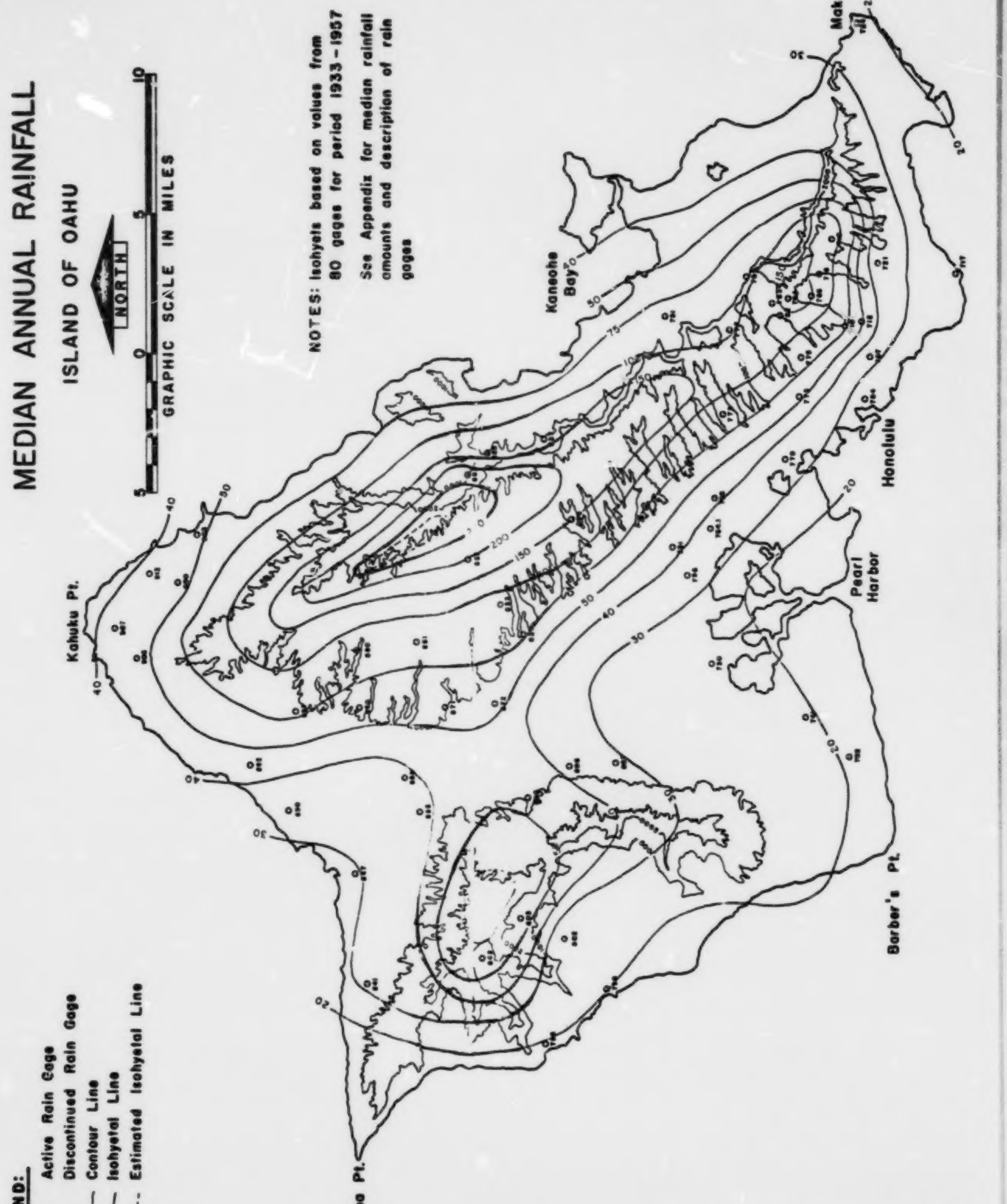
LEGEND:

●	Active Rain Gage
♦	Discontinued Rain Gage
—1000—	Contour Line
—20—	Isohyetal Line
---200---	Estimated Isohyetal Line

MEDIAN ANNUAL RAINFALL

ISLAND OF KAUAI

Figure 7



MEDIAN ANNUAL RAINFALL

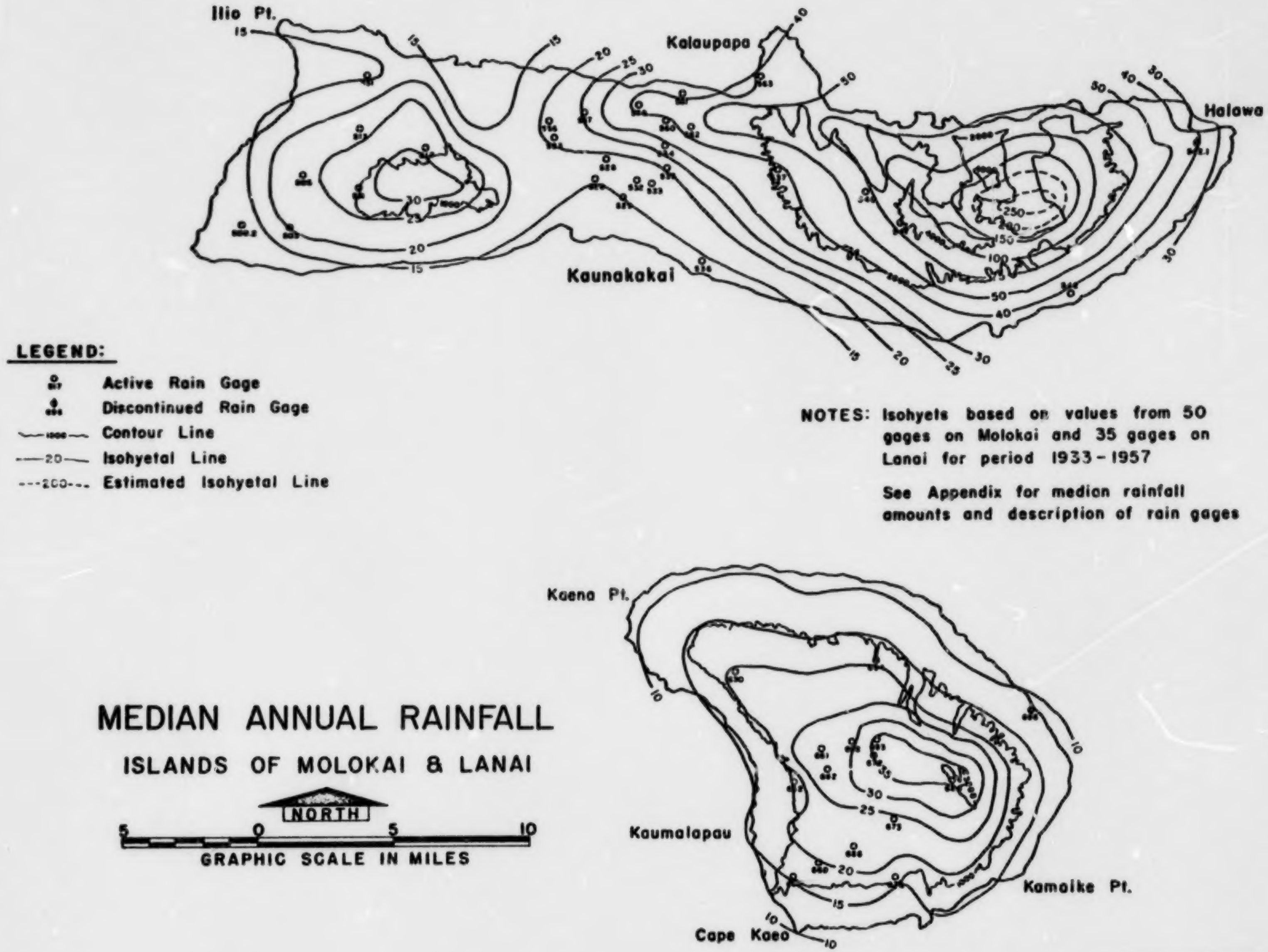
ISLAND OF OAHU

NOTES: Isohyets based on values from 80 gages for period 1933-1957

See Appendix for median rainfall amounts and description of rain gages

NORTH
GRAPHIC SCALE IN MILES
5
0
5
10
LEGEND:
Active Rain Gage
Discontinued Rain Gage
Contour Line
Isohyetal Line
Estimated Isohyetal Line
Kahuku Pt.
Kaena Pt.
Barber's Pt.
Pearl Harbor
Honolulu
Kaneohe Bay
Makapuu I
40
50
30
20
75
100
150
200
10

Figure 8


Ilio Pt.
Kalaupapa
Halawa
Kaunakakai
Kaena Pt.
Kaumalapau
Kamaike Pt.
Cape Kaeo
15
20
25
30
40
50
75
100
150
200
250
35
10
NORTH
5
0
5
10
GRAPHIC SCALE IN MILES

LEGEND:

- Active Rain Gage
- Discontinued Rain Gage
- —1000— Contour Line
- —20— Isohyetal Line
- ---200--- Estimated Isohyetal Line

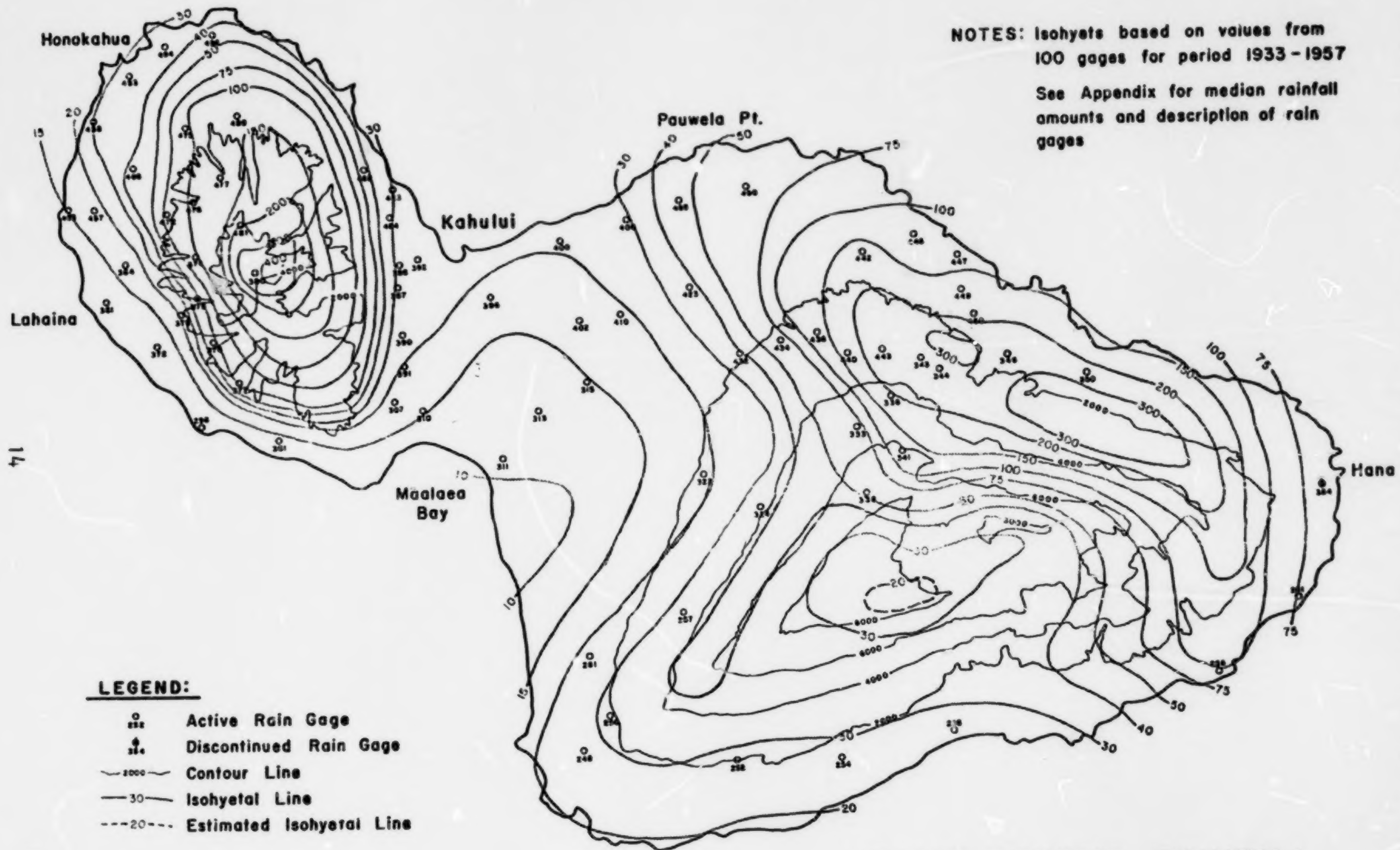
NOTES: Isohyets based on values from 50 gages on Molokai and 35 gages on Lanai for period 1933-1957

See Appendix for median rainfall amounts and description of rain gages

MEDIAN ANNUAL RAINFALL

ISLANDS OF MOLOKAI & LANAI

Figure 9

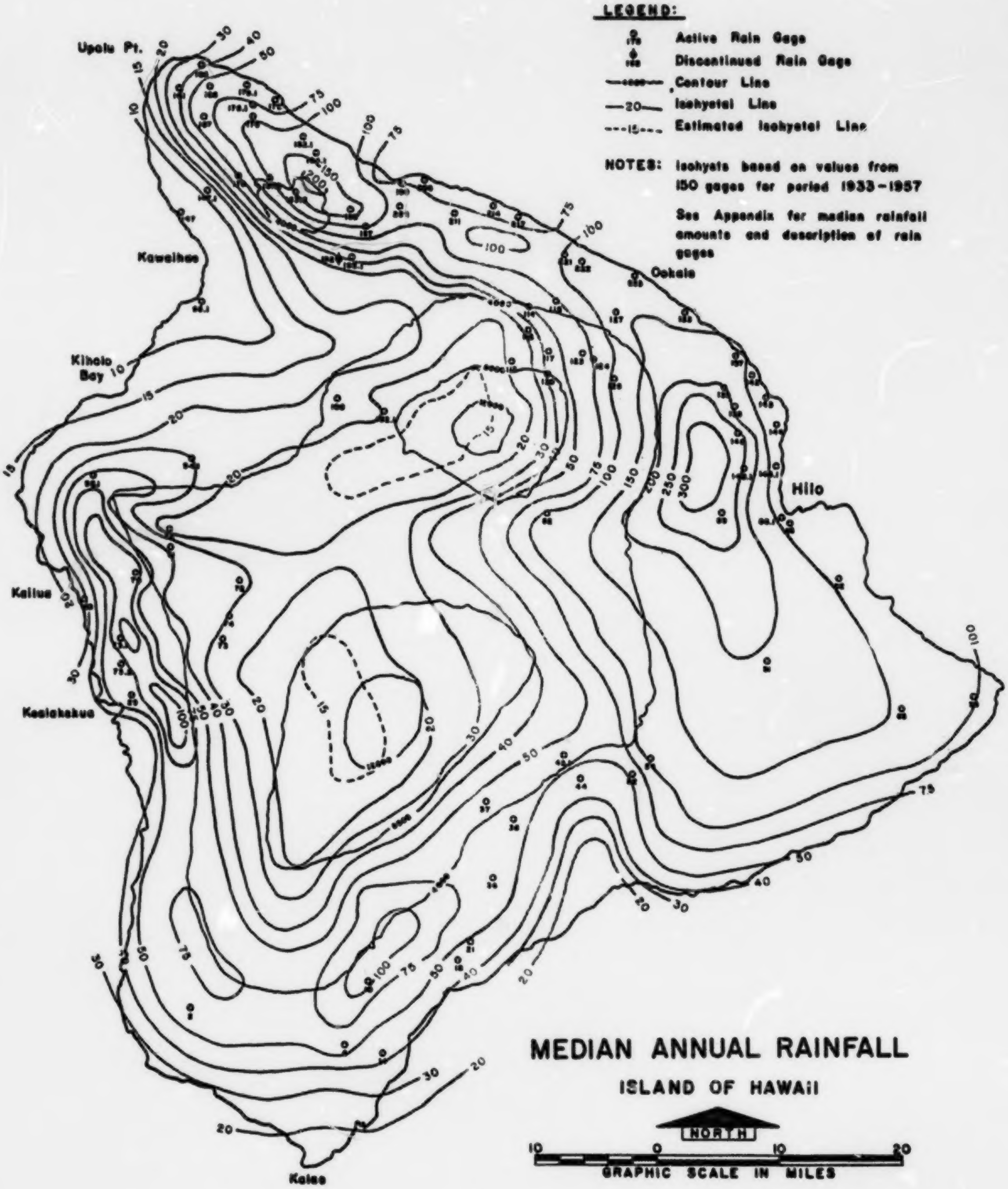

NOTES: Isohyets based on values from 100 gages for period 1933 - 1957
See Appendix for median rainfall amounts and description of rain gages
Honokahua
Lahaina
Kahului
Pauwela Pt.
Maalaea Bay
Hana
LEGEND:
Active Rain Gage
Discontinued Rain Gage
2000 Contour Line
30 Isohyetal Line
20 Estimated Isohyetal Line
10
15
20
30
40
50
75
100
150
200
300
2000
4000
6000
8000

MEDIAN ANNUAL RAINFALL

ISLAND OF MAUI

Reproduced from best available copy.

Figure 10


LEGEND:
Active Rain Gage
Discontinued Rain Gage
Contour Line
—20— Isohyetal Line
---15--- Estimated Isohyetal Line
Upolu Pt.
Kawaihae
Kiholo Bay
Kailua
Kealakekua
Kalae
Ookala
Hilo
NORTH
10 0 10 20
GRAPHIC SCALE IN MILES

NOTES: Isohyets based on values from 150 gages for period 1933-1957

See Appendix for median rainfall amounts and description of rain gages

MEDIAN ANNUAL RAINFALL
ISLAND OF HAWAII

Figure 11

of the above-mentioned plan, but they indicate a trend.

TABLE III

POPULATION BY ISLAND AND YEAR
STATE OF HAWAII

	Total Population (Resident military included)					
Island	1910	1920	1930	1940	1950	1960
Kauai	23,744	29,247	35,806	35,636	29,683	28,541
Niihau	208	191	136	182	222	259
Oahu	81,993	123,496	202,887	257,664	353,020	468,678
Molokai (incl. Kalawao)	1,791	1,784	5,032	5,340	5,280	5,373
Maui	28,623	36,080	48,756	46,920	40,103	36,900
Lanai	131	185	2,356	3,720	3,136	2,202
Hawaii	55,382	64,895	73,325	73,276	68,350	63,383
Total	191,909	255,912	368,336	423,330	499,794	632,772

There is also a surprisingly (to the writer) vigorous development of subdivisions even in fairly remote locations on the above-named islands. Land is fairly expensive, but these subdivided areas appear to be popular.

The hotel and subdivision development on Oahu during recent years is phenomenal. Hotels and apartments are being built at a high rate. Numerous subdivisions are being developed in various parts of the island. The largest of these is the Kaiser development to the east of Honolulu which will eventually provide houses for 55,000 persons. In fact, the construction industry is at a record 268.5-million-dollar-a-year rate and is exceeding the tourist industry as an economic factor according to the Report of the Bank of Hawaii.

All of these developments anticipate a very substantial population growth. The major problems created are those related to water supply and sewage disposal which have been discussed later in this report.

Resources

The major resources on which the State must depend, at least for the present, are the military, the tourist, the sugar and pineapple industries, cattle, and a few lesser agricultural operations.

The military is a basic factor in the economy of Hawaii. According to the Bank of Hawaii 1962 Economic Report, "it is the biggest single activity, the largest employer of Hawaiian manpower, and the greatest single source of Island income." Military installations, especially in the Pearl Harbor area, have some real problems of sewage and waste disposal. In fact, Pearl Harbor is the State's major polluted area.

Tourism is closely associated with water, especially in the Hawaiian situation. Most of the resorts of the Islands are located in beach areas where there are water-related recreational opportunities. There is little doubt that the number one tourist attraction is water, and this factor places more emphasis on the need for maintaining the State's waters in a clean and attractive condition.

There are 27 sugar plantations on Hawaii employing about 14,000 persons. The cane is processed in mills to produce raw sugar which, except for one refinery located on Oahu, is sent to the Mainland for refining. It is possible that more refining will be done on the Islands in the future. The raw sugar produced is worth $145,000,000 yearly. Both the field and mill operations may be factors which affect water quality.

Pineapple production is second only to sugar as an agricultural resource. Canned pineapple products reached a peak of $125,000,000 yearly in 1958 and 1959. There is presently an indication of a recession in the pineapple industry due to competition of foreign markets. Pineapple lands of a number of plantations are reverting to cane or grazing, and canneries are closing or consolidating. As in the case of sugar, field and cannery operations may have an effect on the quality of the water resources.

Potential Resource Development

Research of soil scientists at the University of Hawaii has indicated an accumulation of aluminum oxide in the soils in high-rainfall areas. In 1958 the State Legislature appropriated $50,000 for bauxite research on Kauai. Deposits of nickel, chromium, manganese, iron, tungsten, columbium and titanium were discovered. Under present conditions it appears that bauxite and perhaps titanium are the most promising mineral resources. Bauxite development will require electric power. A proposal for the construction of a hydroelectric power dam and reservoir on Kauai is under consideration, but allocation of the use of this power for an aluminum industry is questionable.

Lumber and pulp and paper is a definite possibility so far as timber resources are concerned. A seven-year study by the Bishop Estates in the Honaunau forest lands of the Island of Hawaii indicates that certain hardwoods show promise for lumber production.

The production of pulp may accompany any sizeable development of a lumber industry.

At the present time a composition board known as "canec" is being produced from sugar-mill bagasse by Flintkote at Hilo. This process has not developed as expected, perhaps due to the lack of a sufficient market for the board. Bagasse is plentiful and it is hoped that this industry will be expanded.

The development of a sizeable heavy industry utilizing native resources is presently not very promising. Industrial development will undoubtedly have to depend upon the agricultural and light industry. There is talk of an electronic industry, of atomic power and of expanding the oil refining operations which presently exist on Oahu. Since the nature of the potential industrial development is not clear, its relation to the water quality problem cannot be anticipated.

WATER RESOURCES

The fresh-water resources of the Hawaiian Islands are related to local rainfall. Rainfall is abundant, but not well distributed. Water is plentiful, but costly to develop. Table IV gives the median precipitation and median quantity of water falling on each of the islands annually as an indication of the rainfall intensity.

TABLE IV

RAINFALL INTENSITY

Island	Area Sq. Mi.	Median Rainfall Inches	Median Rainfall Billion G/Y
Kauai	555	99	956
Oahu	604	58	610
Molokai	260	42	190
Maui	728	75	950
Lanai	141	21	5
Hawaii	4,030	75	5,270

Water falling as precipitation does not normally travel far on the surface, but rapidly enters the soil and ground water. There are a few perennial streams, especially on Kauai, and in many cases streams result only from intense rainfall rates. However, as indicated by Table V and Figure 12, considerable surface water is used, largely for irrigation, on all of the islands.

TABLE V
QUANTITY OF WATER FROM VARIOUS SOURCES - 1957
MG PER YEAR

	Kauai	Oahu	Maui	Lanai	Molokai	Hawaii	Total
Surface	168,520	28,619	129,337	---	412	83,746	410,634
Ground:							
Basal	14,543	149,060	96,092	---	640	8,542	268,877
Other	695	18,082	477	658	3	1,577	21,492
Unidentified	136	---	---	---	1	---	137
Total							701,140

TABLE VI
WATER USE - 1957
MG PER YEAR

	Kauai	Oahu	Maui	Lanai	Molokai	Hawaii	Total
Domestic	3,115	24,410	2,203	90	458	3,880	34,156
Irrigation	156,909	141,835	205,921	522	513	16,129	521,829
Livestock	30	173	25	---	25	154	407
Industrial	23,826	28,429	11,483	46	60	70,794	134,638
Other	14	914	6,274	---	---	2,906	10,110
Total	183,894	195,761	225,906	658	1,056	93,865	701,140

WATER USED BY SOURCES

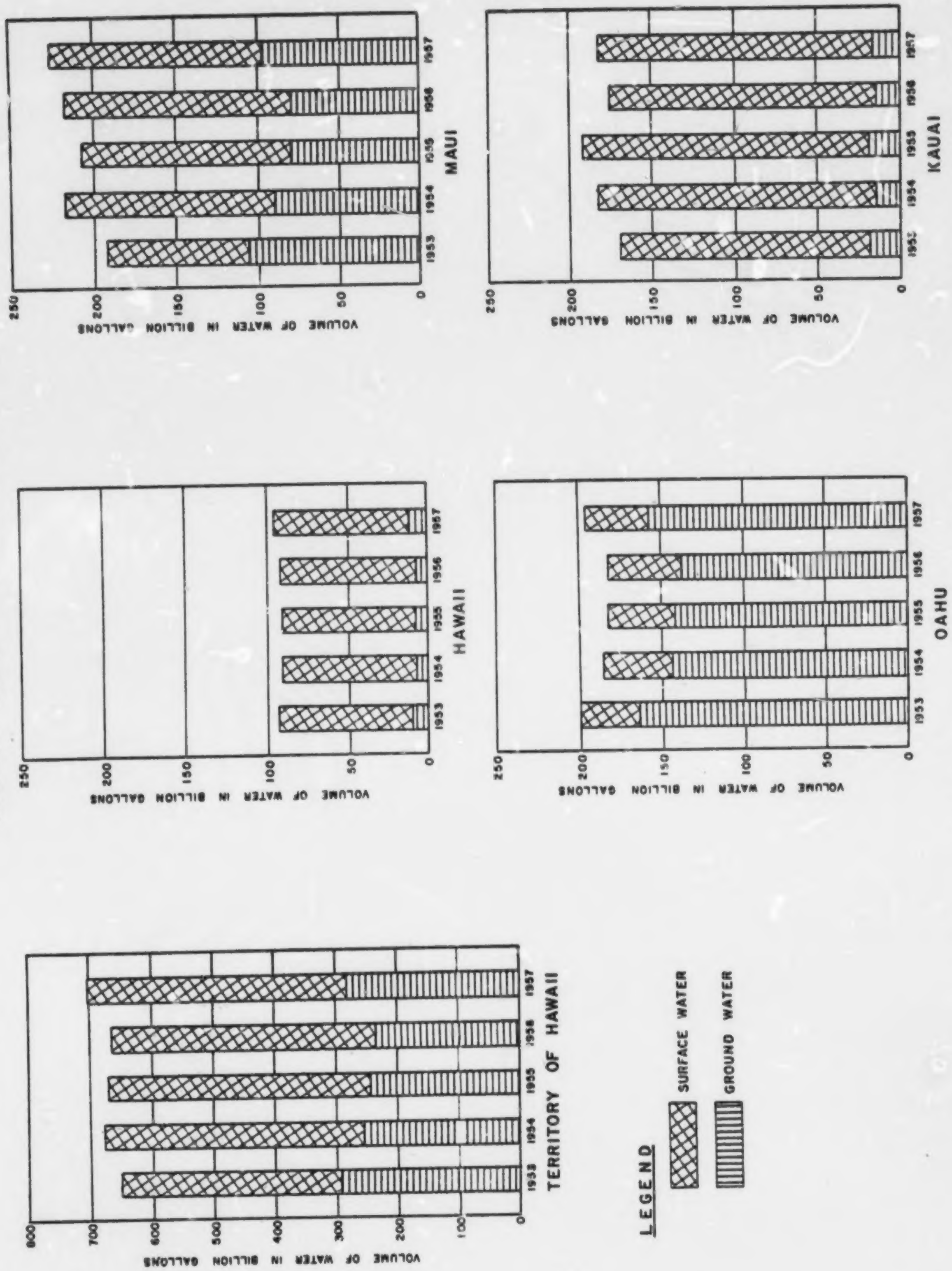


Figure 12

Groundwater

Water which enters the ground, unless utilized, eventually reaches the ocean by subterranean inflow or by surface springs. On Oahu much of the fresh-water flow to Pearl Harbor is due to springs which originate at the thin edge of the cap rock. It is estimated that on this island alone 200 million gallons per day of ground water are lost to the ocean.

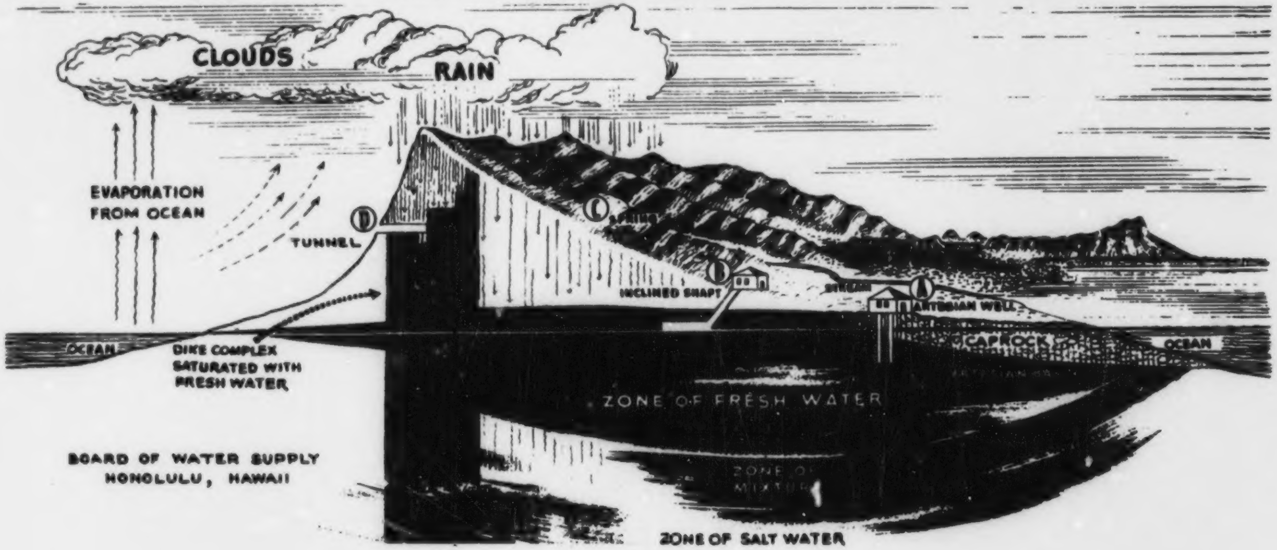
However, there is a considerable storage of ground water on the Islands and it is the most dependable source of fresh water. Ground water is classified according to its occurrence into four groups. (These are illustrated in Figure 13.)

1. Basal water which underlies most of the islands and which is floating on salt water is, to date, the major source of domestic supply. These fresh-water layers form as lenses according to the Ghyben-Herzberg principle. Their surface may be from sea level to 20 to 30 feet above sea level. The depth of the fresh water varies and may be as much as 800 to 1000 feet. There is a transition zone of brackish water between the fresh and salt-water layers. Studies have indicated that mixing of salt with the fresh water is due to movement rather than diffusion. Movement is caused by tidal action and by excessive pumping especially from deep wells which have been used more extensively for irrigation purposes than for domestic supply. Preventing the mixing or intrusion of salt water into the fresh-water lenses is a major problem in those areas where the demand for basal water is greatest. The Board of Water Supply on Oahu has initiated a unique method of removing basal water which is designed to reduce the rate of movement in the lenses. This method consists of an incline shaft and horizontal skimming tunnel (See Figure 13.) The latter is located at sea level and skims the fresh water from a considerable area, thus reducing water movement in depth. The Board of Water Supply presently has three installations of this type. A well-designed tunnel is capable of producing from 15 to 30 mgd.

The important item in connection with basal water is that, in spite of its close proximity to land development and use, no evidence of bacterial contamination has been found. Whether this is true of other types of contaminants has not been determined.

2. Diked water is that which is impounded between impervious vertical rock formations. These dikes were formed when lava cooled under pressure in the volcanic vents. Diked water may extend from high elevations to below sea level. It is usually developed at high elevations by tunnels through the dikes into the water-bearing rock and is transported by gravity for use in lower levels.

SCHEMATIC CHART SHOWING HONOLULU'S WATER SOURCES


CLOUDS
RAIN
EVAPORATION FROM OCEAN
D
TUNNEL
C
SPRING
B
INCLINED SHAFT
STREAM
A
ARTESIAN WELL
CAPROCK
OCEAN
OCEAN
DIKE COMPLEX SATURATED WITH FRESH WATER
ZONE OF FRESH WATER
ZONE OF MIXTURE
ZONE OF SALT WATER

BOARD OF WATER SUPPLY
HONOLULU, HAWAII

Figure 13

3. Perched water is that held on horizontal impervious rock formations or ash beds.

4. Shallow ground water is normally found at low elevations, but separated from the basal water by relatively impervious layers. This source includes water from the cap rock. It is usually brackish and its use limited.

Surface Water

There are no large watersheds on the Hawaiian Islands. However, there are numerous small streams on steep slopes which carry water from high-rainfall areas. Because of the steep slopes and pervious soil and rock, there are few areas where sizeable reservoirs are possible. Three fairly large reservoirs have been constructed, one on Oahu and two on Kauai. Plans are under consideration for a third on Kauai.

Surface waters have been extensively developed, largely by the sugar cane plantations for irrigation. Table V shows the surface water use on the various islands in 1957.

As a rule, streams on the windward side of the islands have a steady flow and seldom go completely dry. Those on the leeward side are flashy and often dry. Flow data is fairly adequate on Kauai and Oahu, but is limited on the other islands. For the most part, these surface streams are considered to be of good quality.

Ocean Water

There is, of course, an abundance of ocean water. The problem is how to use the inshore water effectively for the disposal of waste effluents without impairing its use for recreation, fisheries, etc.

WATER USES

Considering the unique character of the water resources of Hawaii, the people who have developed the water supplies for the various islands, and especially Oahu, should be commended for an excellent job. Responsibility for the development of water supplies lies with the water-supply boards of the four counties and with the sugar plantations under the supervision of the Division of Water and Land Development, Department of Land and Natural Resources. Irrigation supplies and a very limited amount of water for domestic use have been developed by plantations. The counties develop the domestic supplies.

Table VI and Figure 14 show the quantities of water used for various purposes on the several islands for 1957. As will be seen,

WATER USED BY TYPE OF USE

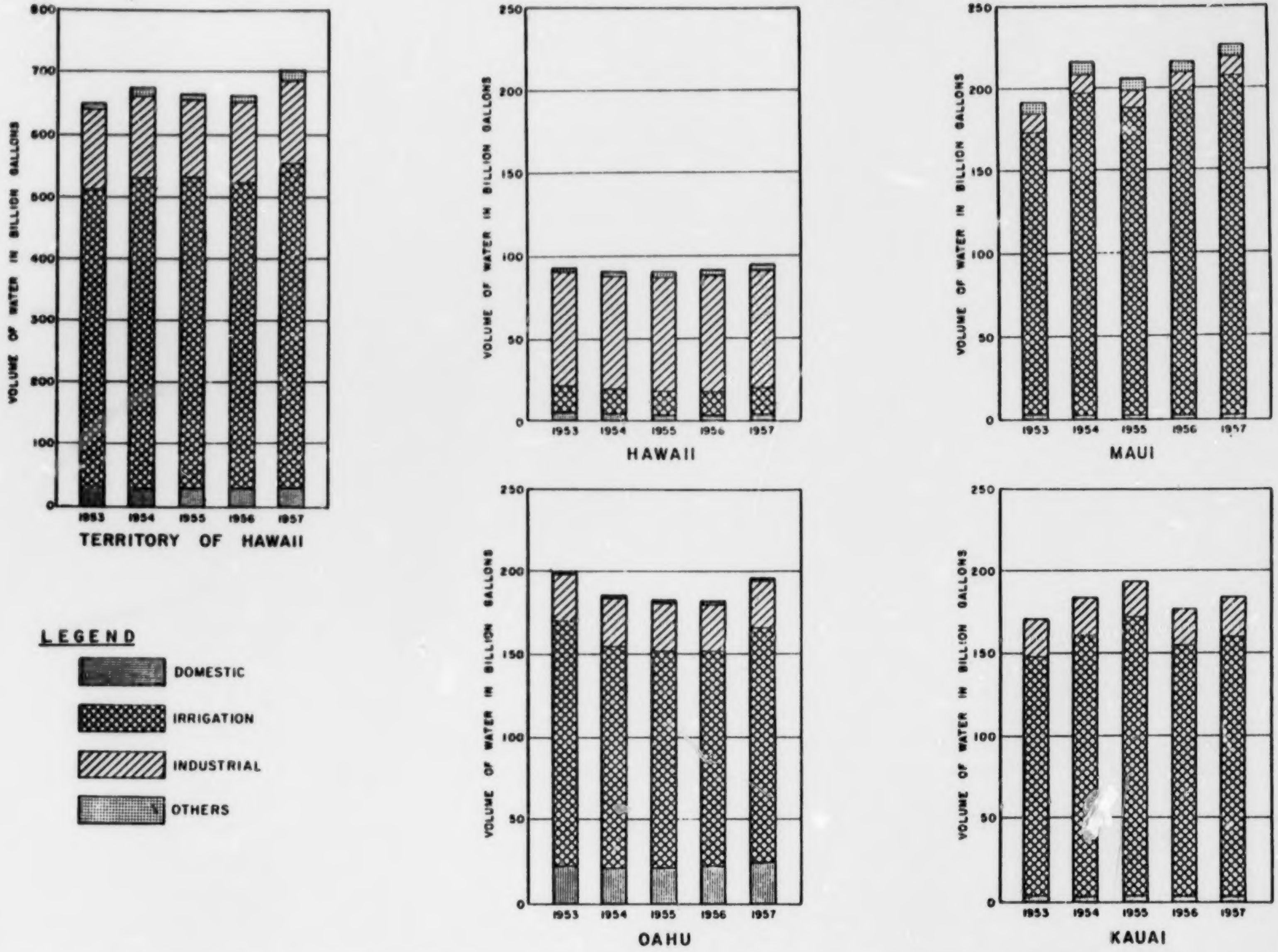


Figure 14

irrigation is the largest user, industrial second and domestic third. Most of the industrial water is associated with the agricultural, either as sugar-mill or pineapple-cannery operations.

Sugar cane is by far the greatest user of water. It is largely applied by surface application (ridge and furrow). From 4 to 8 inches are applied per round with from 10 to 20 rounds per year. The yearly use is 8 to 9 acre-feet and, in some cases, may go as high as 10 acre-feet. Sprinkler irrigation is coming into use and will cut the water requirement in half besides aiding in the harvest by eliminating the need for trenches.

Pineapple growers have recently started spraying with a limited amount of water, depending upon the needs of the crop. The average application is one half acre-foot per year.

Truck crops, of which there is a small acreage, require from 2 to 3 acre-feet per year. Alfalfa requires about 5 acre-feet per year.

Note

More detailed information regarding the water resources of the State of Hawaii are available in numerous publications such as:

"Water Resources in Hawaii," Hawaii Water Authority, March 1959.

"General Reference Guide for Irrigation Project Planning in Hawaii," Hawaii Water Authority, March 1957.

"Oahu Water Plan," Board of Water Supply, City and County of Honolulu, March 1963.

"An Inventory of Basic Water Resources Data - Molokai," Division of Water and Land Development, Department of Land and Natural Resources, January 1961.

SEWAGE AND WASTE DISPOSAL

Cesspools

The pervious nature of the soils and rock formations in almost all parts of the Islands makes the use of cesspools for both sewage and industrial wastes attractive. This method of disposal is in general use and has been fairly successful in removing waste material from local premises.

Cesspools are of various depths and many times are said to be in the water table. In some cases, as in the Lawai area of Kauai, shallow pools are necessary (not over 12 feet deep) to avoid discharge directly into lava tubes. This is not true in other parts of the State, for example the Hilo area where advantage is taken of lava tubes to facilitate sewage disposal from cesspools. In many cases, however, they are 60 or more feet in depth.

Many highly-populated areas and all rural areas use this method for the disposal of sewage. Smaller industries such as milk plants and slaughterhouses dispose of wastes into cesspools.

Because of the presence of basal water underlying most of the areas, it is difficult to understand why this water has escaped serious contamination. It is said that there never has been a confirmed test for B. coli in community water supplies taken from deep wells in artesian-water areas. Whether or not contamination of other types is present, detergents for instance, has not been given adequate study. Certainly this large amount of material must go somewhere.

Sewage Treatment

In recent years there has been a vigorous program of sewage collection involving, in most cases, sewage treatment. This is often an expensive undertaking because it requires the construction of collection systems in highly-developed areas. In other cases, the cost must be carried by comparatively few people due to a sparse population in areas which are only starting to develop. The State Department of Health and the counties that have the responsibility for providing the systems are doing a very commendable job and should be congratulated on the progress made. Mention will not be made here of the individual sewage problems. The Department of Health is well aware of these problems and they are a part of the "Comprehensive Water Pollution Control Program for the State of Hawaii."

As previously indicated, subdivision development is proceeding at a rapid rate. Fortunately, laws are such as to require the review and approval of sewerage plans by the Health Department and apparently the policy is to require sewers and treatment in all of these new areas. Temporary plants are being constructed in many cases pending the installation of permanent facilities. Rated-aeration package plants have proven invaluable as temporary installations since sewage lagoons are not often feasible due to the unavailability of large tracts of inexpensive land and the permeability of the soils. For the same reasons most permanent plants of the future will probably employ the activated sludge or trickling filter processes. The use of lagoons will be extremely limited unless some inexpensive way of compacting the permeable type of soils is developed.

Industrial Waste Disposal

The major industrial wastes to date are those of the sugar and pineapple industries. The sugar mills produce only raw sugar which is sent to California for refining, except one mill on Oahu which refines sugar for local use. Pineapple is processed in the Islands' canneries.

Sugar Mill Wastes

A major waste problem of the sugar mills is that of the disposal of dirt and trash hauled to the mills from the fields. This problem has increased manyfold due to the mechanizing of cane harvesting methods. The old method of cutting the cane by hand and stripping some of the leaves before hauling has largely been discontinued due partly to the cost of labor. The machine in most use pulls the cane and loads it with all the dirt and trash. In wet weather the amount of soil thus moved is such that in one case a mill equipped to recover the soil was able to produce 15 acres of new cane land per year. In many cases adequate equipment is not available to remove the soil from the wash water.

The solution for much of this problem lies in developing a different type of harvester or in field cleaning. This is a soil conservation measure as well as a water pollution problem. In discussing this matter with representatives of the Hawaiian Sugar Planters' Association it was found that their research is being aimed in this direction. In the meantime, some mills are installing Dorr hydroseparators and recovering the soil for new land. Also, in many cases a portion of the water is reused for irrigation.

Another waste product of the sugar mill is the bagasse (cane after juice is removed). This material is often discharged with the liquid wastes. In some cases it is burned as fuel and in one case it is sold to a company for the manufacture of composition board. The use of this material constitutes another industry problem.

The liquid wastes from the sugar mills in general are discharged to the ocean. This is especially the case on the Island of Hawaii. The attitude of the industry seems to be that this is a proper means of disposal or that the damage done does not warrant the expenditure necessary for treatment.

Pineapple Cannery Waste

The wastes from the processing of pineapple are somewhat normal to those of the usual cannery operations. There is considerable solid waste consisting of the shells. In most cases this material is dried, ground and supplemented for sale as pineapple bran. The bran is used as stock feed. Other by-products have been developed from juices such as citric acid, alcohol and, more recently, a meat-tenderizing enzyme. These processes are not in general use on the Islands.

The liquid wastes, however, contain considerable solid matter, sugars and other material in solution. It was observed that some screens used for removing the suspended material were not efficient. Wastes are ponded or discharged to the ocean. In one case especially, Hawaiian Fruit Packers, Island of Kauai, odors from the fermentation of wastes in ponds have caused considerable complaint. It is apparent that the waste disposal problems of this industry have not been completely solved.

Table VII lists each of the major industries and discusses briefly the waste disposal methods used.

TABLE VII

INDUSTRIES AND INDUSTRIAL WASTES

KAUAI

Pineapple

Kauai Canneries Lawai	Juice solids and waste water are discharged to the ocean through a 6-inch outfall. Pineapple which is not suitable for canning, and other solids from the process, are dumped over the cliff into the ocean about a half-mile west of the outfall. At one time consideration was given to the installation of equipment to process peelings for cattle food and for the incineration of solid wastes. However, it is determined that this mill will close in 1965 and that the lands now used for pineapple will revert to sugar cane and cattle grazing.
Hawaiian Canners, Inc. Kapaa	This cannery has been closed and the pineapple land has reverted to sugar cane and cattle grazing.

Hawaiian Fruit Packers Kapaa Heights	The waste from this cannery is discharged to three lagoons where it is allowed to decompose with final discharge to the ocean. The company has had considerable difficulty with the production of odors from these lagoons. A survey was made a number of years ago by Hayse Black of the Taft Engineering Center. However, to date, no answer has been suggested for the control of odors. It was learned from the Pineapple Research Institute that this company does not have a drier or bran plant for the production of cattle feed. Such an installation might help the odor problem by reducing the amount of material to the ponds. (Subsidiary of the Stokley-Van Camp Corp.)

Sugar

McBryde Sugar Co. Port Allen	A hydroseparator was installed in this plant in 1953. The overflow is collected in a reservoir and the water used for irrigation. Some of the waste water from the fields discharges to the ocean. There is some evidence of mud on the shoreline but the situation is not serious. Mud and rock are used for fill and the bagasse is burned.
Grove Farm Company Koloa	Wastes from this mill go to ponds and a portion of the pond effluent is used for irrigation. The remainder discharges to the ocean.
Lihue Sugar Company Lihue	Wastes from this mill discharge to a hydroseparator and the effluent is used for irrigation. A portion of the effluent discharges through a series of flumes and tunnels to the ocean. The ocean is badly discolored especially during wet weather. Trash and mud are hauled to the fields.

Kilauea Sugar Co. Kilauea	Wastes from this mill are ponded and a portion used for irrigation. A considerable amount of the wastes is flumed to a large gulch from which it finds its way to the ocean. There is considerable evidence that mud and bagasse are on the shore. Plans are under way to truck some of the bagasse to the fields.
Olokele Sugar Co. Makaweli	Wastes from this company are not treated but are used for irrigation with a considerable discharge to the ocean. Bagasse is hauled to the fields. Plans have been considered for the installation of a hydroseparator.

Miscellaneous

Waimea Dairy Waimea	All milk pasteurized and a small amount of cottage cheese, cream and skimmed milk produced. Waste discharged to cesspool.
Maheloma TB Hospital Dairy Maheloma	This hospital operates a dairy farm and pasteurizes milk for its own use. Wastes go to cesspool.
Sokei Dairy Farm Sokei	This farm pasteurizes milk for local trade. All wastes are discharged to cesspools.
Slaughterhouses	There are six slaughterhouses on the Island of Kauai. Blood and washings go to cesspools which are said to operate without difficulty.

OAHU

Pineapple

Libby, McNeill & Libby Co. Dole Corporation California Packing Corp. Honolulu	Concentrated wastes are discharged to the Honolulu system - the weak wastes to Kapalama Canal. Occasionally the concentrated wastes also go to the canal.

Sugar

Kahuhu Plantation Kahuhu	Waste material and soil are discharged to a diked area which overflows to a large pond. The pond water is pumped to the ocean. Trash is hauled to Sand Plain and burned. The company is considering the installation of a hydroseparator.
Ewa Plantation Ewa	Silt is removed from the waste water by a hydroseparator and the overflow used for irrigation. Sludge from the hydroseparator is used to develop new cane land at the rate of about 15 acres per year.
Oahu Sugar Company Near Pearl Harbor	Excess bagasse and waste water used to reclaim land for irrigation. Considerable waste is allowed to flow into Pearl Harbor, causing a muddy condition of the harbor waters and damaging fish and shellfish.
Waialua Agricultural Co. Waialua	A hydroseparator is used to remove dirt which is returned to the cane fields. Water is pumped back to the fields for irrigation.

Miscellaneous

Honolulu Gas Co. Honolulu	Wastes are run through a 3-million-gal. settling tank where a wetting agent is added to settle the tars. Water goes to Kapalama Canal after passing through two skimming pits. Lamp black is trapped in the tars and is burned in boilers. Wastes are said to destroy bait fish in Honolulu Harbor.
Pacific Chemical & Fertilizer Co. Honolulu	Salt water used for cooling. Waste water from the iron sulfate plant is discharged to a ditch leading to Kapalama Basin at Pier 35.

Standard Oil Co. - Refinery Barber's Point	Wastes passed through oil separators and lagoons prior to discharge to the ocean.

MAUI

Pineapple

Baldwin Packers Lahaina	This plant has been abandoned and the operation moved to Kahului.
Baldwin Packers Kahului	Wastes are screened through a screen with 5/8-inch openings and discharged to the Kahului sewer system. Solid wastes are processed as stock food known as pineapple bran.
Libby, McNeill & Libby Pauwela	Wastes are discharged to Kuiaha Gulch. Very little reaches the ocean. Solids are sold for feed (plant presently closed).

Sugar

Hawaiian Commercial & Sugar Co. Puunene	Wastes are passed through a hydroseparator from which solids are used to reclaim land and the water for irrigation.
Hawaiian Commercial & Sugar Co. Puunene	Wastes are passed through a hydroseparator and the solids are used to reclaim land and the water for irrigation. If water exceeds the demand, it overflows the separator into a reservoir and then discharges to the ocean. It is proposed to install a pump to lift the water into one of the main irrigation ditches and avoid this overflow.
Pioneer Mill Lahaina	This mill has no hydroseparator, but has an extensive series of ponds which discharge to the ocean about 3 or 4 miles south of the plant. Rock and mud collected in the ponds is hauled with other trash to a gulch. Some waste water is used for irrigation. Difficulties with odors and shoreline deposits have been reported.

Wailuku Sugar Co. Wailuku	Wastes from this plant pass through a hydroseparator and from there to a pond with final discharge to Iao stream. The ocean area between the mouth of the Iao stream and Kahului breakwater is badly polluted. This is an area of about 5 acres in extent. Soil and dirt removed by the hydroseparator is hauled to the fields to be used as top soil. Some water from the hydroseparator is used for irrigation. (During the time of the visit the hydroseparator was not in use and the ponds were overgrown and apparently had not been used recently.)

HAWAII

Sugar

Puna Sugar Co. Olaa	This mill is located from 10 to 15 miles south of Hilo, inland from the ocean. All of the waste is lagooned with no overflow.
Hakalau Plantation Hakalau	This mill is located on the northwest coast of the Island which for the most part is precipitous with few, if any, beaches. All of the waste from the mill is discharged into the ocean. It is planned that a portion of the bagasse be used for commercial purposes.
Paauhau Plantation Paauhau	This mill is also located on the northwest coast and wastes are dumped over the cliff to the ocean.
Hawaiian Agricultural Co. Pahala	Wastes from this mill are disposed of on land with no apparent odor or pollution problem. The mill is not located near the ocean. Bagasse is collected and hauled to the fields.
Hutchinson Sugar Plantation Co. Naalehu	Bagasse from this mill is burned for fuel. Waste from the cane washers is flumed directly to the ocean, and the ocean and shore in the vicinity are covered with debris and mud.

Onomea Plantation Onomea	Another mill located on the northwest coast discharging waste water and bagasse directly to the ocean.
Hilo Sugar Co. Hilo	Trash, waste water, and bagasse discharged to Hilo Bay. This mill differs somewhat from many of the other mills in that 87% of the cane is hand-cut and the remainder is field-cleaned which considerably reduces the amount of soil and debris in the mill waste.
Pepeekeo Plantation Pepeekeo	This mill located on the northwest coast discharges wastes directly to the ocean. A limited amount of hand cutting of cane has reduced the content of the waste to some extent. The plantation hopes to dispose of the bagasse to the Flintkote Co. in Hilo for the manufacture of composition board.
Kohala Plantation Kohala	This mill is located on the north tip of the Island. Waste and trash are discharged to a deep gulch 3/4 of a mile from the ocean. While much of the trash and silt are retained in the gulch, the ocean is discolored for a distance of a half mile from shore. This plantation plans to adopt field cleaning to reduce its waste problem.
Hamakua Plantation Hamakua	Another mill on the northwest coast which dumps its refuse and waste over the bluff. This material builds up on the shore and ocean bottom where it deteriorates, causing an unsightly condition.
Honokaa Plantation Honokaa	A mill on the northwest coast where all material from the operations is flumed to the ocean. The company hopes to provide field cleaning to reduce the waste.

Kaiwiki Plantation Ookala	All waste material is dumped over the bluff into the ocean where it rots, causing an unsightly condition.
Laupahoehoe Plantation Laupahoehoe	Another northwest coast mill dumping all waste material over the bluff into the ocean. This company also hopes to adopt field cleaning.

(NOTE: The plantations along the northwest coast of Hawaii have formed a cooperative and eventually a number of the sugar mills may be abandoned and the operations combined in a few of the existing mills.)

Miscellaneous

Flintkote Co. Hilo (Canec Division)	This company uses bagasse from the sugar plantations as raw material for the production of a composition board. The wastes are discharged to the Wailoa River a short distance from Hilo Bay in a park area. On the occasion of a visit to this area, there was no apparent pollution in the river; however, the plant had not been operating for some time. The Wailoa River is the shortest river in the U. S.
Hilo Gas Company Hilo	It is said that this company has no industrial wastes.
Ultramar Chemical Corp. Hilo	No wastes.
Royal Hawaiian Macadamia Nut Co. Keaau	This is a dry process and has no apparent liquid wastes.
Milk processing plants	There are five milk processing plants on the Island of Hawaii, three of which are combination farm and plant. One is a dairy manufacturing butter and cottage cheese. The wastes from all of these plants are discharged to cesspools without treatment, which is said to be a satisfactory method of disposal.

American Factors, Inc. (Kona Branch, Kailua - Kona) Island of Hawaii	This company processes coffee. Wastes are discharged to cesspools from which they drain rapidly. These wastes will go to the Kona sewer system and plant when completed.
Captain Cook Coffee Co. Napoopoo	(See above statement)
Pacific Coffee Cooperative Kealakekua	(See above statement)

LAND OPERATIONS

Table II indicates that 222,000 acres of land in the State of Hawaii are used to produce sugar cane and about 75,000 for pineapple. Growing these crops, as well as others, requires the use of fertilizers, pesticides and weedicides. Almost all types of such substances are in use on the Island, but certain ones predominate. For instance, aqua ammonia is applied with irrigation water in some stages of cane growth. Urea is the most common fertilizer used for both cane and pineapple. It and other types of fertilizers are applied by airplane.

Herbicides such as WONURON and DIURON, which destroy weed seeds, are applied to soil. The total rate of application to a three-year crop of pineapple is from 12 to 14 lbs per acre. Four pounds per acre are applied initially, four to six during the first two years, and a final four pounds the third year. Other selective herbicides are used and are sprayed on the plants. In the case of cane this is done by airplane as are the insecticides. 2-4-D cannot be used on pineapple but is used on sugar cane. Malathion is among the insecticides applied. Iron as ferrous sulfate is sprayed on the leaves of pineapple where it is absorbed. According to soil scientists at the University, "iron in the soil is not available to the plants because of its tie-up with manganese."

On the Mainland, the number of chemicals available as pesticides and herbicides, and their increased use during recent years, has caused concern regarding their presence and effect in natural waters. Since on the Islands large quantities of these materials are used, and since large amounts of irrigation water are applied and the permeability and rate of infiltration of the soils and rock formations are high, a similar problem may result in the basal water. At least, this is a question which should be answered.

REFUSE DISPOSAL

Another factor which may or may not affect the water quality problem is that of refuse or solid waste disposal. Dr. D. W. Ryckman, of Washington University at St. Louis, has been employed by the University of Hawaii to teach and conduct studies on the solid waste disposal problem. There is no doubt that Dr. Ryckman will take into account the probable water quality problem in his recommendations for refuse disposal.

FISH AND SHELLFISH

Contacts with the Fish and Game Division of the State of Hawaii indicate a deep concern regarding the effects of pollution on the native fishery. The major concern seems to be for the nehu which is a bait fish necessary for commercial fishing for tuna. This fish spends much of its life in the brackish waters of Pearl Harbor, Kaneohe Bay, Hilo Harbor, Ali Wai Canal and other protected areas.

Large amounts of bait are required by commercial fishermen. It is recorded that in 1949 almost 300,000 lbs. of nehu were used. The commercial catch of tuna and other usable fish amounts to about 19 million pounds per year, worth over three and a half million dollars.

While there is concern regarding the effects of pollution on the fishery, no comprehensive study has been made to assess these effects, especially in the coastal-water areas.

Another factor which has just recently come to the attention of the fisheries agency is that of a potential oyster resource. Eastern oysters planted in Pearl Harbor have shown a phenomenal growth. Dr. Albert Sparks of the Fisheries School, University of Washington, was employed to study the potential of the Islands for oyster production and his report was extremely favorable.

However, Pearl Harbor is so badly contaminated that oysters grown there cannot be marketed and should not be used even locally. It has been suggested that the oyster be allowed to reproduce in Pearl Harbor and then be transplanted, probably in the "spat" stage, to unpolluted areas. The south shore of Molokai has been suggested by Dr. Sparks as one favorable area. The question of how long must an oyster remain in the unpolluted area to be cleared of bacterial contamination and be saleable is yet to be resolved.

THE OCEAN

Under the present state of knowledge it is evident that the near-shore ocean in the various areas will be the major receiving water for sewage, industrial and other types of wastes after they have been given the necessary treatment. Because these nearshore waters and their onshore areas are closely tied to the future economic development of the Islands as resort, recreation and homesite areas, it is imperative that sewage and waste treatment be initiated as preventive measures and that the points of discharge be properly selected.

While the general trend is toward treatment prior to ocean disposal, there is considerable raw sewage being discharged through ocean outfalls. The notable example, of course, is Honolulu where presently all sewage from sewered areas is discharged through a 78-inch outfall off Sand Island. Recreational and resort areas are gradually encroaching on this location and some action toward treatment may soon be in order. The Department of Health is supporting a study of the ocean in this area during the summer of 1963.

Because of the importance of the inshore ocean waters for effluent disposal, there is need for a comprehensive study in selected areas on all the islands and according to established priorities. Some such studies have been made or are in the making.

ITEM II

WATER QUALITY PROBLEMS

NOTE

The discussion which follows presents in a brief and general way the water quality problems of Hawaii and the research needed to cope with them. The research projects suggested have been developed individually and in more depth in Item IV.

Having considered the unique characteristics of the land, climate, economy and water resources of the State of Hawaii, an attempt will now be made to assess the existing and potential water quality problems. The fact that water quality problems may exist is no reflection on the efforts of the very able State agencies who are most certainly doing a commendable job. The facts are that serious problems of water quality are not yet common in Hawaii, undoubtedly due to the efforts of these agencies.

However, conditions are changing, especially on Oahu and to a lesser extent on the other islands. Living conditions are different than they were five or ten years ago. Traffic is becoming a problem. The pace of living has increased and many of the problems of the Mainland which were not previously problems on Hawaii are now appearing.

The increase in population is, of course, a factor in causing this change, but this may not be the only factor. Industry has not shown an exceptional growth and agriculture appears fairly stable, but construction (hotels, resorts and homes) and real estate development have taken a tremendous upsurge.

Thus, the major problems of water quality are those related to domestic water supply and to sewage and solid waste disposal. While this situation is recognized, there are a number of unknowns involved in these areas regarding which research is needed.

The purpose of research is not only to solve problems, but often to determine if a problem exists or has potential. Thus, through research, problems may be anticipated and avoided.

WATER SUPPLY

Basal Water

Of the various subsurface sources of domestic or community water supply, namely basal, diked and perched, the one most subject to quality changes or contamination is the basal water. (This statement omits the shallow waters which will not be major sources of supply, but which are subject to contamination.) It has long been recognized that the basal water is a most important source of domestic water and must be protected. Consequently, numerous studies have been made with this objective in mind.

The major problem of basal water contamination has been and continues to be salt-water intrusion. Most of the research effort to date has been rightly directed toward this problem and, although it appears to be well in hand, it is imperative that the effort not be relaxed, but rather be enhanced.

However, there are other potential sources of basal water contamination which require study. The first of these, of course, is that of bacterial and viral contamination. Although continuing tests of existing supplies have produced little evidence of the presence of B. coli, there is no explanation of why this is the case, or assurance that it will continue. There is a need for more adequate knowledge regarding the travel and fate of fecal organisms in the special types of soils and rock formations of the Islands. These soils and formations are called upon to handle large amounts of domestic sewage and industrial wastes and in view of the location of the basal water with respect to cesspools the lack of contamination is unusual. Of course, the construction of sewer systems will reduce the use of cesspools, but there are still many years ahead before cesspools will be eliminated as a potential source of contamination. This study should also include the fate and travel of viruses which is a subject on which little information is available.

Other important potential contaminants, the use of which has increased during recent years, are the fertilizers, pesticides and herbicides used on crops, along roadside right-of-ways, and around homes. As indicated in Item I, most of the numerous types of chemicals available today for the control of pests are in use on the Islands. Contamination of water by these substances is a problem of the Mainland and most certainly is a potential one on Hawaii and one that may already exist. Studies involving basic-data techniques, especially carbon-filter analysis, are needed to determine whether the problem does exist and, if so, its magnitude. Soil studies using lysimeters and test plots are needed to determine the fate of these substances and the possibility of their entrance into the basal waters.

Another potential source of basal water contamination is the land disposal of garbage and refuse. As previously indicated, this source of contamination will undoubtedly be considered when methods of refuse disposal are adopted for general use.

Recharge of ground water using surface water, irrigation return flow, or treated industrial waste and sewage effluents may be necessary at some future period, especially in areas of low precipitation and short water supply. Many of the above-mentioned problems will be involved in the recharge operations and the information gained by the suggested studies will aid in the planning for recharge.

Substances involving heavy metals are often used in agricultural and industrial operations. For instance, it is said that arsenic was used indiscriminately for many years as a weedicide. Where such metal ions are concerned, knowledge regarding chemical reaction, adsorption, ion-exchange, etc., in the various soils is important to the groundwater problem.

Soils of the Islands are high in the concentration of heavy metals - copper, cadmium, manganese, iron, etc. What is the fate of these metals during weathering and do they enter the basal water? The apparent absence of iron may indicate that they do not; still there seems to be a problem involved here for the soil scientist which may in some way relate to the quality of the basal water.

Related to the above problems, and indirectly involving water quality, is the need for more information regarding the factors which influence the direction and velocity of the lateral movement of ground water. This may explain many of the problems of contamination or lack of contamination and may guide future selections of locations for the withdrawal of basal water.

Ocean Disposal

As previously indicated, the nearshore waters of the ocean are and will be the major disposal areas for the effluent from sewage and waste treatment facilities. Because of the value of these waters and adjacent beaches and shore lands for recreation, fisheries and homesites, the proper selection of disposal locations and methods is imperative in order to avoid damage to these uses.

For instance, much more knowledge is needed regarding: inshore or nearshore currents on all of the islands; the effects of waves and wind on the travel of sewage fields; the proper use of reefs and their effects on mixing; and the variation in current direction and velocity due to wind, tide and reefs. Nearshore disposal requires the solution of many complex problems if effective mixing of effluents and salt water is to be accomplished.

It is said that ocean disposal of sewage can be satisfactory only in channels where the flow is away from the coast and is most efficient during the part of the cycle when the outward flow is the strongest. This would indicate that in some cases controlled intermittent discharge may be desirable. If so, the question is how can this best be done and what structures and equipment are required?

Studies are also needed to determine the best methods to obtain maximum diffusion to prevent the formation of a "slick" or sewage field. A type of outfall which will provide for mixing effluent and salt water in the outfall line prior to discharge may be the answer and suggests a subject for an engineering study.

Consideration should be given also to determining differences in inshore conditions between the windward and leeward sides of the Islands as regards the disposal of effluents.

The Hawaiian Institute of Geophysics is presently engaged in a study of coastal currents in respect to sewage disposal and has recently published an Interim Progress Report No. 1, "Currents Around the Hawaiian Islands," by Don E. Avery, Doak C. Cox and Taivo Laevastu. (Jan. 1963). This report contains much preliminary information regarding the coastal waters.

In addition to the studies of the Hawaiian Institute of Geophysics, the State Department of Health has carried on several studies of coastal currents at Kailua-Kona, Hilo Bay, Kahului Harbor and in Honolulu shore waters; the City and County of Honolulu have studied coastal currents at Kailua, Oahu and Waianae; and a private developer has made coastal studies at the Hawaii-Kai development off Kokohead.

Fish and Shellfish

Related to the oceanographic problems of the ocean disposal of effluents is their effects on the aquatic life of the nearshore and estuary waters. There is a definite need for a comprehensive study of this subject to determine the extent and nature of the fisheries problem as it exists or may be anticipated. Fisheries agencies of the State feel that pollution is affecting the bait-fish populations especially in harbors and bays such as Pearl Harbor and Hilo Bay. They also feel that the bagasse and trash of sugar mills affect the aquatic life in the areas of waste discharge.

Mention was made in Item I of the potential of an oyster industry to supplement the economy of the State. Pollution and bacteria contamination is a limiting factor in the development of such an industry, since it interferes with the marketing of the oyster. It has been suggested that reproduction of oysters take place in Pearl Harbor, which is highly contaminated but where conditions have been proven favorable, and that the young oyster be moved to other uncontaminated areas for growth and marketing. Studies are required regarding the effect of time on the self-cleansing of the oyster and on the locations of the areas where the oyster can be successfully grown. Experience on the Mainland will guide this study.

The above-suggested research of the fishery problems will require the establishment of water quality criteria for the type of fish and shellfish involved. Such criteria have not been definitely established for Mainland fish except in case of a few elements. This may represent a major research project for Island fish. The knowledge, however, is essential to any other studies of water quality effects on aquatic life.

INDUSTRIAL WASTES

Sugar Mills

The major industrial waste disposal problem of the Islands is that of the sugar mills. As previously indicated, the methods of harvesting the cane are responsible for a major portion of the problem. It seems reasonable, therefore, to emphasize the need for an accentuated effort to develop harvesting methods which will leave most of the soil and trash on the field. The industry is well aware of this problem and is making some effort to develop new types of harvesting equipment. Correction of the waste disposal problem, however, does not seem to be the impelling factor.

While improved harvesting equipment will reduce the magnitude of the waste problem, there still will be a need for waste treatment and this matter should be given further study. Bagasse disposal or utilization also is an area for research. Attention is directed to "An Industrial Waste Guide to the Cane Sugar Industry" which was prepared by the U. S. Public Health Service from experiences of the industry on the Mainland.

Pineapple Canneries

Much of the solid material from the processing of pineapple, as well as a portion of the juices, may be utilized for the production of pineapple bran. There is a considerable demand for this bran as cattle feed on the Islands. However, this operation does not eliminate all of the solids contained in the liquid wastes. It is suggested that studies to improve the efficiency and type of screens used to recover a larger portion of these solids are in order.

Where bran is manufactured and screens effective, the liquid wastes appear to respond to lagoon treatment. In one case on the Island of Kauai difficulties have been experienced with odors from ponded waste. In this case, drying and grinding equipment for making bran is not available. Also, the screen on the liquid waste line does not appear to be an efficient installation. The utilization of the solid waste and juice for the production of bran and improved screening would, in this case, reduce the load to the lagoons and might improve the odor situation.

Research is needed regarding improved methods of cannery-waste treatment after the efficient removal of suspended solids. It is suggested that controlled fermentation or conventional oxidation may prove effective. If lagoons are to be used effectively for this waste, design criteria must be established. This has not been done. Also, the use of the waste for irrigation should be investigated. The National Canners' Association at Berkeley, California is conducting pineapple research. The canneries of the Hawaiian Islands are members of this Association.

Oil Refinery

The Standard Oil Company refinery located at Barber's Point on the Island of Oahu has had difficulties with the operation of treatment facilities which have resulted in loss of oil to the nearshore waters of the ocean. These difficulties, however, are mechanical and do not suggest the need for research.

SALT-WATER CONVERSION

The Hawaiian Islands, because of their location and state of development, will undoubtedly be a center of education, research and culture for a large area of the Pacific. This has been recognized by the establishment of the Hawaii Institute of Geophysics, facilities for which are under construction at the University of Hawaii.

Many islands and atolls of the Pacific, as well as the Island of Lanai and certain local areas on other islands of the State of Hawaii, do not have sufficient water for self-perpetuation. Hence, there seems to be a field for saline water conversion research and some interest in this study has been indicated. Because of the predominance of sunshine in most of this area, interest has been largely directed toward studies of demineralization of sea water by solar radiation.

Field and Laboratory Methods

Related to and often a necessary part of water quality research is the development and standardization of field and laboratory methods. While these methods may not be specific to the State of Hawaii, the studies they represent are certainly justified as a part of the research effort.

Among the methods needed are:

1. Tracers for ground-water studies. Some suggested substances for study are chlorides, sugar, helium, tritium, florescent dyes and radioisotopes.

2. Tracers for oceanographic studies.

3. Adaption of carbon filter and basic-data techniques to ground-water studies, especially the basal water.

4. Improved methods for measuring the adsorptive, desorptive, and exchange capacity of soils as related to the chemistry of water which passes through it.

ITEM III

INVENTORY OF RESEARCH

NOTE

This item contains an inventory of the entities of the State of Hawaii that are known to have a direct interest in research on subjects related to water quality, with brief statements about their responsibility and capacity to do research in this field and the projects under way. It is hoped that the assessment in each case is essentially correct. If not, an adjustment will be made gladly if the writer of this report is notified. There may be individuals, companies or agencies of the Islands interested in conducting research in this field that have not been included here. The writer will also be pleased to hear of them since it is desired to make this inventory as complete as possible.

DEPARTMENT OF PLANNING AND RESEARCH

The State of Hawaii differs in its approach to research from most other states in that it has in the Reorganization Act provided for the coordination of the research effort by a Department of Planning and Research. (On May 16, 1963 the Governor signed an Executive Order merging the Department of Planning and Research with the Department of Economic Development. The new Department is called "Department of Planning and Economic Development.") Such high-level coordination is considered necessary because 12 administrative departments of the State have at least one division with the primary responsibility of conducting research. The purpose of the Department is to prevent duplication, plan programs to prevent over-emphasis in some areas and lack of emphasis in others, and to provide uniformity and comparability in procedures and coverage.

The Department has, under date of June 27, 1962, compiled Research Report 24 which is a directory of State agencies involved in research and containing statements of their respective responsibilities and functions. The scope of activities over which coordination is exerted covers almost all of the physical and social sciences within the interests of state government. However, this Department does not conduct research as such.

STATE DEPARTMENT OF HEALTH

The State Department of Health, because of its responsibility in the fields of environmental health, water supply and water pollution, has a deep and direct interest in research on water quality subjects.

The Division of Environmental Health has excellent laboratory facilities for support of field operations and is especially well equipped for radiological analysis. Since the work of the Division is largely an enforcement operation, research is not a major function and laboratories and personnel are not especially adapted to this type of study. However, because the Division recognizes the need for new knowledge, which can only be gained through research, studies of this type by other entities have been and apparently will continue to be supported within the limits of the Division's ability to do so.

UNIVERSITY OF HAWAII

The University of Hawaii is developing rapidly in all appropriate areas of education and research. It is apparently the objective of the University's administration to make the University a center of education, research and culture of the Pacific. Closely integrated with the University is the Center for Cultural and Technical Interchange between East and West, known as the "East-West Center".

Considerable emphasis is placed on the development of the Graduate School. A Division of Research administers and organizes all research programs except those of the Agricultural Experiment Station, the Bureau of Business Research and the Engineering Experiment Station.

Among the divisions of the University indicating an interest in water research are the following:

The Hawaii Institute of Geophysics which, in cooperation with the various departments of the University, promotes research in physical and chemical sciences. A water laboratory will be contained in the new Institute Building which will be completed in 1963. This laboratory will be used for ground water and oceanographic research. An oceanographic study of "coastal currents in relation to sewage disposal" is presently under way involving, among others, the School of Engineering and the U. S. Fish and Wildlife Service. Among those occupied with this project are: Prof. Don E. Avery of the Department of General Engineering; Doak C. Cox, Executive Secretary of the Institute; and Taivo Laevastu, Associate Professor of Oceanography. Mr. Cox is also an expert on ground water.

The Department of Public Health is growing rapidly under the leadership of Dr. Richard K. C. Lee. This Department is located in the new Health Research Building which contains excellent facilities and equipment for research in environmental health under a Visiting Professorship of Environmental Health and Engineering. Dr. D. W. Ryckman, on leave from Washington University in St. Louis, is presently engaged in developing a graduate program in Environmental and Sanitary Engineering which should stimulate added interest in water quality research. This program includes research studies on solid waste disposal problems of the Island of Oahu and is being developed as a joint effort with the Department of Civil Engineering.

The School of Engineering, under Dean Wilfred Holmes, has a major interest in research in the water field, largely centered in the Civil Engineering Department. Facilities for research are not adequate at the present time for a major research effort, but are being developed on a cooperative basis with the Department of Public Health, as noted above.

Dr. L. Stephen Lau brings from the University of California a considerable experience in salt-water intrusion research which is being used with the support of the Honolulu Board of Water Supply in studies of sea-water intrusion in Oahu's basal water. Prof. W. W. Tinniswood, of the Civil Engineering Department, under contract with the State Department of Health, will conduct oceanographic studies in the vicinity of the Honolulu outfall during the summer of 1963. A hydraulic model of Pearl Harbor basal water area has been used for studies of salt-water intrusion and ground-water movement. This model simulates the underground strata with percolation to scale and may be adapted to studies of the movement of contaminants such as pesticides, etc.

The Department of Agronomy and Soil Science has a special interest in soils and soil water as they may affect the basal water quality. This interest is centered in Dr. G. Donald Sherman who indicated his intention to develop a study in this area with Dr. Martin Sherman of the Department of Entomology and Dr. Swindale, Professor of Soils. Excellent facilities are available in these departments for this type of research.

The Department of Meteorology and Oceanography has done considerable excellent work on ocean currents around the Islands and has recently initiated studies of nearshore currents with the Institute of Geophysics. The Department is well equipped for such studies.

The Hawaii Marine Laboratory, located on Coconut Island in Kaneohe Bay on the windward side of Oahu, has facilities for research in the marine biology of the Islands.

In the Department of Microbiology, Dr. Oswald A. Bushnell has indicated an interest in research related to the water quality problems. Dr. Bushnell has under way a project on the history of infectious diseases in Hawaii and the survival time of certain types of bacteria in frozen fruits, and might also become interested in studies of the fate of organisms in the soil and rock formations.

STATE DEPARTMENT OF LAND AND NATURAL RESOURCES, DIVISION OF WATER AND LAND DEVELOPMENT

The Department of Land and Natural Resources has the responsibility to inventory the mineral and water resources of the State and to conduct research studies. The Division cooperates with the U. S. Geological Survey on the collection of stream-flow data and conducting hydrographic studies. One of its major functions is the preparation of a comprehensive water plan for each island. Some of these plans have been completed, such as the domestic water plan for the Island of Molokai which has been published as Report R18.

Research of the Division to date has not involved water quality although this matter is presently being discussed with the Geological Survey. Contact with Mr. Walter O. Watson, Jr. who is assistant to Robert T. Chuck, Manager-Engineer, indicated an interest in a study of the possible contamination of basal water by seepage from irrigation. Because of the major responsibility for water research invested in this Department, it is one of the important entities for the study of water quality. Facilities for this type of study will need to be developed further.

HONOLULU BOARD OF WATER SUPPLY

The State of Hawaii has no incorporated municipalities and only four counties. The governmental bodies of these counties are responsible for the domestic water resources of the respective counties. The Board of Water Supply for the City-County of Honolulu is responsible for publicly-owned domestic supplies for the entire Island of Oahu. This Board has recently published the "Oahu Water Plan" designed to provide supplies and systems to meet the anticipated growth pattern of the Island.

This Board has resources for research although this is not considered to be it's major function. Only recently has research regarding water quality been initiated. A project under way in the Pearl Harbor area was designed to study the effect of irrigation on the basal water. However, the primary element determined was chloride with only an occasional test for nitrates. The Board has applied to the State Department of Health for a grant to study the effect of the discharge of the effluent from a sewage treatment process on the basal water. This effluent is discharged to a series of seepage pits from which it seeps into the subsurface strata.

Although the Board has excellent laboratory facilities for the control of the water supplies, its facilities for research in the quality field are limited. Also, since personnel are not yet assigned solely to research, the priority of other activities interferes with the adequacies of such studies. Apparently, however, there is an increasing interest in water quality research and the potential is there for a substantial effort.

U. S. GEOLOGICAL SURVEY

Although the Survey has a substantial program for studies of both ground and surface water resources of the Islands and has published many excellent papers on the subject of quantity, the matter of quality has been given limited attention. No quality branch exists on the Islands although interest in this phase of the water problem has been indicated.

STATE FISH AND GAME DIVISION

A deep concern regarding the effects of pollution on fish and shellfish was expressed by Mr. Michio Takata of this Division. He indicated that no comprehensive study has been made to determine what, if any, effects are exerted by pollution on the coastal fishery.

The Division has facilities for coastal studies but lacks the necessary laboratory and personnel for a research effort in water quality. The interest, however, is there and it appears that the facilities of the Division may be expanded to allow for this type of study. Of major interest at this time is the development of the oyster industry. The principal deterrent to this development is pollution. Recognition of this situation may provide the impetus for a water quality project.

BUREAU OF COMMERCIAL FISHERIES

The responsibility of the Bureau is apparently limited to the deep ocean fishery. Hence, the Bureau is not involved with research regarding the Islands' water quality problems.

STATE DEPARTMENT OF AGRICULTURE

Research of this Department is indirectly involved with water quality in its responsibilities regarding the safe use of insecticides, weedicides and herbicides. It is hoped that the water contamination problem will be considered in the research on this subject.

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

All water for irrigation use is developed by the sugar plantations. Plantation sugar mills are the major source of industrial wastes. These two factors indicate the responsibility of the plantations and the Association regarding research on water quality problems.

Most of the responsibility for research regarding waste disposal methods is probably that of the plantations through their research entities. The attitude of the plantation management that waste disposal from the mills is not causing water pollution problems precludes a major research effort regarding methods of waste treatment. Utilization of bagasse and conservation of soil and quantity of water, however, are subjects receiving considerable attention.

PINEAPPLE RESEARCH INSTITUTE OF HAWAII

This Institute has no program involving research of waste disposal or treatment from pineapple canneries. Dependence for such studies is invested in the National Canners' Association (especially the Berkeley, California Laboratory.)

INVENTORY OF PROJECTS

The list which follows is an inventory of research projects in progress, unless shown to be recently completed or in the planning stage, on subjects which appear to be directly or indirectly concerned with the water quality problems of the State of Hawaii. This list was compiled partly from contacts, partly from the quarterly reports of the former Department of Planning and Research, and partly from a summary of University of Hawaii research prepared by a University Research Committee. The list may not contain all projects under way and may be corrected by notifying the writer of this report. The project list is followed by a selected list of publications which are considered pertinent to the subject of water quality.

In some cases it may be difficult to see the relationship of a project listed to water quality. This has been a matter of interpretation by the writer. For instance, Project No. 4, "Market for Extruded Aluminum Products," is of interest as a forecast of probable water use and waste disposal problems. Many other projects are in the same category. Actually, there are very few projects related directly to water quality.

STATE DEPARTMENT OF AGRICULTURE

1. Studies to determine the most effective and economical herbicides for the control of noxious plants, Black Wattle and Fire Bush.

2. Effect of methyl bromide fumigation on germination of 4 species of weeds. (Completed and published.)

STATE DEPARTMENT OF HEALTH

3. Studies of mosquito resistance to insecticides.

DEPARTMENT OF ECONOMIC DEVELOPMENT

4. Market for extruded aluminum products. (Completed.)

5. Economic potential of the proposed dam in the Kohee area on Kauai. (Completed.)

6. Citrus fruit potential in Hawaii.

STATE FISH AND GAME DIVISION

7. Survey of fishermen and creel census.

8. Experimental marine fish-tagging study.

9. Study of the oyster resource in Hawaii.

10. State-wide limnological survey and catalog of streams.

11. Introduction of aquatic insects and other invertebrates.

12. Reef and inshore game-fish management research.

13. Fresh water game-fish management research.

FORESTRY DIVISION, DEPARTMENT OF LAND & NATURAL RESOURCES

14. A multiple-use program for the State forest lands of Hawaii. (Completed.)

15. Forest land-use classification.

16. Program of watershed management research, silvi-cultural research, forest products research and forest survey.

DIV. OF WATER & LAND DEVELOPMENT, DEPARTMENT OF LAND & NATURAL RESOURCES

17. A domestic water plan for Kaunakakai-Pukoo, Molokai. (Published.)

18. Relationship of State Water Program and the U. S. Geological Survey. (Published.)

19. Lahaina water study, Maui - a domestic water development plan for Lahaina.

20. Flood control plan for State of Hawaii.

21. General water plan for Island of Molokai.

22. Keauhou test plot studies, Keauhou, Hawaii.

DIV. OF WATER & LAND DEVELOPMENT, DEPARTMENT OF LAND & NATURAL RESOURCES WITH U. S. GEOLOGICAL SURVEY

23. Preliminary summary of findings in water resource studies on windward Oahu, Hawaii. (Completed.)

24. Kohala-Hamakua water study, Hawaii - development of water availability and planning.

25. Water resources studies of the Mokuleia-Waialua area, Oahu.

26. Water resources studies of the Waianae area, Oahu.

27. Effects of land use and water use.

28. Effect of the Haiku Tunnel on Kahaluu Stream, Oahu, Hawaii.

DIV. OF WATER & LAND DEVELOPMENT, DEPARTMENT OF LAND & NATURAL RESOURCES WITH U. S. BUREAU OF RECLAMATION

29. Kokee project - feasibility study and project development plans.

DIV. OF WATER & LAND DEVELOPMENT, DEPARTMENT OF LAND & NATURAL RESOURCES WITH HAWAIIAN SUGAR PLANTERS' ASSOCIATION

30. Solar radiation data collection.

DIV. OF MINES, DEPARTMENT OF LAND & NATURAL RESOURCES WITH U. S. BUREAU OF MINES

31. Metallurgical testing of Hawaiian ferruginous bauxites. (Published.)

DIV. OF MINES, DEPARTMENT OF LAND & NATURAL RESOURCES WITH U. S. GEOLOGICAL SURVEY

32. Preliminary report on investigation of ferruginous bauxites and plastic clay deposits on Kauai and Maui. (Completed.)

STATE DEPARTMENT OF PLANNING & RESEARCH

33. Shoreline recreation survey, 1962.

HARBORS DIV. OF DEPARTMENT OF TRANSPORTATION WITH MARINE ADVISORS, INC.

34. Wave height and frequency studies of selected Oahu beaches.

UNIVERSITY OF HAWAII

Economic Research Center

35. Future of Hawaiian sugar industry.

36. Hawaiian economic indicators.

Department of Agriculture

37. Types of occurrence of nontronite and nontronite-like minerals in soils.

38. The vanadium content of Hawaiian Island soils.

Engineering Experiment Station

39. Technique of model analysis.

40. Sea-water intrusion in ground-water aquifers. (For Honolulu Board of Water Supply.)

Institute of Geophysics (See planned project list.)

41. Surface currents, causes and predictions. (In press.)

42. General shoreline study.

43. Coastal currents project.

Land Study Bureau

44. An urban land-use study on Oahu.

Department of Botany

45. The role of algae in the central and western Pacific. Maxwell S. Doty.

Department of Chemistry

46. Seasonal variation of iron and silicate in Hawaiian waters. Harry Zeitlin and K. Lei.

47. The determination and distribution of trace elements in sea water. Harry Zeitlin and G. Gopalreddy.

Department of Civil Engineering

48. Ground-water motion in coastal aquifers. L. Stephen Lau. (Transitional zone from fresh to sea water in a ground-water aquifer.)

49. A field investigation of the infiltration capacity of some soils on Oahu. L. Stephen Lau. (Completed.)

50. Development and hydrology of ground-water basin with special reference to sea-water encroachment in Honolulu region. L. Stephen Lau.

51. Determination of permeability-coefficient by pumping tests in a two-miscible liquid system. L. Stephen Lau.

52. Zone of transition of the Ghyben-Herzberg lens as affected by pumping. L. Stephen Lau.

Department of Civil Engineering with Honolulu Board of Water Supply

53. Water development of Kalauao Basin springs - hydraulic model studies. L. Stephen Lau.

Department of Geological Sciences

54. Geochemistry of calcium carbonate from noncoralline algae in Hawaiian marine sediments. R. Moberly, Jr.

55. General shoreline study of Hawaiian Islands. R. Moberly, Jr.

Department of Meteorology & Oceanography

56. A study of surface currents. Taivo Laevastu.

Department of Public Health

57. The Development of a graduate research program in environmental and sanitary engineering. D. W. Ryckman.

58. Solid waste research program for Oahu. D. W. Ryckman.

Department of Zoology

59. The estimation of vital parameters in fish populations. B. S. Muir.

60. The oxidation and temperature relationships of marine fish in an active state. B. S. Muir.

61. Accumulation of radioisotopes by marine organisms - accumulation and transfer of $_{CR}^{51}$ in an artificial marine ecosystem. S. J. Townsley.

Institute of Geophysics (Planned Projects)

a. Measurement of surface and bottom currents off natural channels within the reefs.

b. Measurement of beach currents inside reefs.

c. Measurement of tidal currents within channels and outside reefs with paddle-wheel current meter.

d. Mapping some convergences (converging currents.)

e. Measurement of tidal currents around Kauai in relation to co-tidal lines.

f. Distribution of sewage off Sand Island under trade-wind conditions.

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"The Role of Fish as Conveyors of Microorganisms in Aquatic Environments," Baker, Gladys E. and Louise F. Potter, Dept. of Botany.

"The Primary Production of Bodies of Water," Vinberg, G. G. (A book translated from the Russian by Maxwell S. Doty, Editor and contributor, Dept. of Botany.)

"Productivity Measurements in the World Ocean," Doty, Maxwell S. and L. R. A. Capurro, Dept. of Botany.

"An Economic Base Study of Hilo-Puna; An Economic Base Study of Kauai; and An Economic Analysis of Oahu," Winter, Lothar G., Dept. of Business.

"Nitrate in Hawaiian Waters," Zeitlin, H. and S. Higaki, Dept. of Chemistry.

"A Modification of The Kay Method for The Determination of Organic Carbon in Sea Water," Zeitlin, H. and T. Mullins, Dept. of Chemistry.

"A Field Investigation of Infiltration for Some Soils on Oahu, Hawaii," Lau, L. Stephen and J. P. Willocks, Dept. of Civil Engineering.

"The Adequacy of Plankton Sampling," Laevastu, T., Dept. of Meteorology and Oceanography.

"The Components of Surface Currents in The Sea and Their Forecasting," Laevastu, T., Dept. of Meteorology and Oceanography.

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"Water Problems in Hawaii," Carson, Max H. Mid-Pacific Magazine 34:27-32, 1927.

"Notes: Research in Ground-Water Hydrology in Hawaii," Cox, Doak C. Pacific Science, Apr. 1954.

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"Geology and Ground-Water Resources of the Island of Molokai, Hawaii," Stearns, Harold T. and Gordon A. MacDonald. (Hawaii - Ter., Div. of Hydrography in cooperation with U. S. Geological Survey - Bulletin No. 11), Honolulu, Apr. 1947. 113 pp.

"Geology and Ground-Water Resources of the Island of Hawaii," Stearns, Harold T. and Gordon A. MacDonald. (Hawaii - Ter., Div. of Hydrography in cooperation with U. S. Geological Survey - Bulletin No. 9), Honolulu, 1946. 363 pp.

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ITEM IV

RESEARCH PROSPECTUSES

The purpose of this item is to present in some detail suggestions for research projects which are considered to be essential to the protection of the quality of the water resources of the State of Hawaii. This program of research is based on the water quality problems which exist or may be anticipated for the future, as outlined in a general way in Item II. The fact that research is suggested here does not necessarily mean that there is a complete lack of information regarding these problems. However, where a project is suggested, it is believed that knowledge is not adequate. In some cases, research is needed to determine if a problem actually exists or is a probability and, if there is a potential problem, research should be initiated to provide the knowledge regarding it. The knowledge gained may be instrumental in preventing the problem from happening.

For the purpose of this report, the program of water quality research has been developed under seven general projects, as indicated in the outline which follows. Each of these projects has a number of overlapping and related phases, especially the basal water problem. Each phase may constitute a separate study, but there should be coordination of the phases to avoid duplication and to make use of related information. No attempt has been made to develop procedures for the studies since these are features which must be left to the ingenuity of the researcher and are actually a part of his study. The real purpose of the prospectus is to delineate the research need as it appears to the writer.

Prospectus No. 1 - Studies of Basal Water Problems

Phase 1 - Salt-Water Intrusion
Phase 2 - Ground-Water Movement
Phase 3 - Fate and Travel of Bacteria & Virus
Phase 4 - Fate and Travel of Fertilizers, Insecticides and Herbicides
Phase 5 - Reactivity of Soils vs. Heavy Metals

Prospectus No. 2 - Ocean Disposal of Effluents

Phase 1 - Oceanographic Study
Phase 2 - Effluent - Salt-Water Mixing

Prospectus No. 3 - Water Quality vs. Fish & Shellfish

Phase 1 - Field Investigation
Phase 2 - Bioassay
Phase 3 - Shellfish Contamination

Prospectus No. 4 - Sewerage

Phase 1 - Sewage Disposal by Irrigation
Phase 2 - Sewage Lagoons
Phase 3 - Combined Sewage and Industrial Wastes
Phase 4 - Sewerage Planning

Prospectus No. 5 - Industrial Waste Disposal

Phase 1 - Cane-Sugar Mill Waste
Phase 2 - Pineapple-Cannery Wastes

Prospectus No. 6 - Salt-Water Conversion

Prospectus No. 7 - Field and Laboratory Methods

Phase 1 - Organics
Phase 2 - Heavy Metals
Phase 3 - Soils

PROSPECTUS NO. 1

STUDIES OF BASAL WATER PROBLEMS

THE PROBLEM

The basal water problems of the Hawaiian Islands are in many ways related to the ground-water problems of the Mainland West Coast states. While the knowledge gained by research in these areas is not necessarily directly applicable to the unique basal water situation on the Islands, the techniques used in the studies of the Mainland problems can in many, but not all, cases be applied to Hawaiian conditions with certain modifications. The distinct difference between the Mainland and Islands ground-water situation, except for the higher permeability of soils and rocks, is the salt water which almost completely underlies the fresh basal water. Salt-water intrusion is a problem of Mainland coastal states, but it is not the same problem as exists in the State of Hawaii.

This basal water situation, and anticipated problems, has been discussed in Items I and II and will not be repeated here except as necessary to develop the research prospectus.

Ground-Water Contamination

Ground water consists of the runoff of precipitation which is absorbed by or percolates into the soil at the surface, moves downward through the zones of aeration and saturation and then laterally to a point of discharge. The character of the soils and rock formations governs the velocity and, together with the force of gravity, the direction of this movement.

Because of the high permeability of the soils and rocks of the Islands (except perhaps Kauai), both the vertical rate of penetration and movement and the velocity of lateral movement must be much greater than in most other areas of this country. Also, the high rainfall occurring mostly at high elevations must create a head which results in an unusual rate of ground-water movement in many, if not most, areas.

Contaminated water follows the same path through the various formations as does uncontaminated water. The same geological factors control the movement of contaminated water as control uncontaminated. The difference lies in the physical, chemical and biological reactions which may occur in the soil or rock and which may remove or alter the contaminating substances. Many of these reactions are not well understood especially as they occur in the soils and rocks of the Islands.

There are a number of potential contaminants of the basal water in addition to salt water from the ocean. Among these are: the sewage bacteria and viruses from cesspools and some types of land runoff; organics from sewage, industrial wastes and soils; fertilizers, insecticides and herbicides from agricultural and forest lands and homesites; and heavy metals contained in the soils and having access to the soil water. To date, these contaminants, except for bacteria (B. coli), have apparently not been found in those basal water supplies which have been subjected to continuous testing. However, except for bacteria (B. coli), few, if any, tests have been made even in these cases. The reason to believe that they constitute a potential problem lies in experience in other areas where the same sources are present. The evidence in these other areas is sufficient to warrant a study here, since once the ground water is contaminated, considerable time is required to free it of the contaminating substances.

Phases of the Project

It may not be practical to undertake the entire basal water research as a single study since the capabilities of a number of disciplines are involved. However, it is desirable to at least coordinate the several phases of the project to avoid some of the inherent duplication and to make use of techniques and facilities which may be similar. Therefore, some type of organized cooperation among disciplines working on the different phases of the project is indicated.

The following breakdown may not be the only or best division of the project, but does represent one way to divide the study among disciplines. Several of these phases may be combined, if found desirable.

1. Salt-water intrusion
2. Ground-water movement and related factors
3. The fate and travel of sewage bacteria and virus
4. The fate and travel of fertilizers, insecticides and herbicides
5. Reactivity of soils as it affects entrance of heavy metals into basal water

PHASE I - SALT-WATER INTRUSION

As previously indicated, the salt-water intrusion problem is the major basal water quality problem of the Islands - at least, according to present knowledge. This problem has been recognized for a long period and is the subject of continuing and excellent research; hence, it will not be dealt with in detail here.

Like many other problems of the Islands, this problem is somewhat unique and requires techniques which differ essentially from those used on the Mainland. For instance, in California salt-water intrusion is largely due to overdraft and excessive removal of fresh water from ground-water aquifers near the coast. Fresh-water barriers have been used in some areas to prevent intrusion of the salt-water wedge. While excessive removal may cause intrusion in basal waters of the Islands, there appears to be the added problem of mixing due to movement. Barriers are apparently not the answer since the fresh water sets as a lens on top of the salt water.

These and other unique factors are recognized and techniques and facilities are being developed or adapted to the study of the problem. One of these is the basal water model located in the engineering laboratories of the University of Hawaii. This model may be adaptable to use in other phases of basal water research.

The following is a partial bibliography of articles on salt-water intrusion. For a complete abstract of the literature on this subject up to 1952, reference is made to Technical Bulletin No. 10, I.E.R. Series 37, Sanitary Engineering Research Project, University of California, "An Abstract of Literature Pertaining to Sea-Water Intrusion and Its Control."

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PHASE 2 - GROUND-WATER MOVEMENT - TRACERS

The research regarding ground-water movement suggested here is largely a field study because of the variations in soil and rock structure which may occur within short distances. Movement is one of the important factors influencing the contamination of ground water. For instance, it is expected that the velocity of water movement, especially lateral movement, is comparatively high in the pervious rock formations of the Hawaiian Islands. If so, this may prevent the accumulation of contaminants or may move them to unexpected locations.

Fundamental studies in fluid mechanics have developed theories and mathematical expressions regarding infiltration, permeability, saturated and unsaturated flow, etc. General information regarding soils and the geology of areas of the Islands is apparently already available. This knowledge is essential to a study of water movement; however, it is usually not sufficiently specific for studies of ground-water contamination. Fissures, lava tubes, impermeable layers and other variations are factors influencing rates and direction of ground-water movement not predictable by the application of theory. There is a need, therefore, for more practical studies of ground-water contamination as it is affected by water movement. Such studies require tools which are not presently satisfactory.

The project suggested here is that of attempting to find a tracer or tracers which are at least qualitative and, if possible, more than qualitative for studies of ground-water movement. Such tracers must be adapted to the nature of the soils and rocks and should not be absorbed, adsorbed or reactive under these conditions. They should not in themselves be significant contaminants. They should be easily detected - quantitatively, if possible - be readily obtainable and not excessively costly. These are fairly strict requirements.

Radioisotopes have been used as tracers, but there are several objections to them. They should not be used in a potable water supply. Also, they may be removed from the water by reactions with other substances in the soils and rocks. These objections do not necessarily eliminate isotopes from consideration, but are important factors in making this study.

Chlorides are not considered satisfactory in this case because of the common occurrence of this ion. Metals may have the same reactive power as the isotopes; however, there may be metal ions which will carry through with the water. This is a possibility which should be investigated.

Some of the more stable detergents may be promising although they are a common contaminant and will require careful controls. Perhaps some of the more exotic chemicals, many of which are extremely stable, will prove to be useful as tracers.

It is suggested that this study be conducted first in the laboratory, using columns containing soils of the area. If a promising tracer is developed, it should then be applied in the field, using drained plots of land and finally a system of wells. If a tracer is successfully developed, a technique should be devised for its practical use.

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PHASE 3 - FATE AND TRAVEL OF SEWAGE BACTERIA AND VIRUS

Sewage bacteria and viruses most certainly have potential access to the basal water of the Hawaiian Islands from a number of sources, but especially from cesspools. Nowhere in the experience of the writer is there such a universal and concentrated use of subsurface disposal of raw sewage as there is on the Island of Oahu (See Item I). And nowhere within the same experience has such concentrated use been practised without problems of soil and water contamination.

Those responsible for delivering a safe water to the public should be commended for their vigilance. Indeed, it appears that they are involved with a fortunate situation and one which it is hoped will continue indefinitely.

Of course, this does not mean that the basal water of all areas is free of bacterial contamination. It is desirable to expand the knowledge in this area in order to know how to proceed or what to prepare for in the future.

A great deal of information on the fate and travel of bacteria in soil and rock formations has been gained elsewhere by many research projects. There is considerable variation in the results of these studies, depending upon the conditions under which the studies were made. The consensus is that the sewage bacteria do not travel far in soils and no more than 200 to 300 feet at the most when injected directly into aquifers. This situation, however, does not necessarily apply to fast-flowing underground water such as in gravel formations where contact of bacteria with rock particles is comparatively infrequent. How it applies to the Hawaiian condition is not known.

Details regarding these Mainland studies are available in the literature and will not be repeated here. Perhaps the most comprehensive are those made in California, and the techniques used there may be adaptable to the studies proposed by this report. (See bibliography.)

In making these studies, it is suggested that attention be given to a possible sterilizing effect of some of the less weathered Hawaiian Islands soils. Such an effect on sewage bacteria may occur because of the high content of salts of heavy metals - copper, chromium, iron and manganese - although this is presently only a surmise on the part of the writer. If these soils have such an effect, it should be correlated with the minerals and their concentration.

The problem of the contamination of ground water by viruses of sewage origin has not received the attention given to sewage bacteria although it may be even more of a public health hazard. The literature refers to many outbreaks of virus infections which are water-borne, hepatitis and polio being among the more serious. A recent report of N. A. Clarke and P. W. Kabler of the Robert A. Taft Sanitary Engineering Center, titled "Human Enteric Viruses in Sewage," summarizes the information available on this subject.

The complex nature of methods of segregation and identification of viruses has been the principal deterrent to this study. Methods of testing are reviewed in the above-referred-to report. It is suggested that this is a fertile field for research. Such studies applied to the basal water of the Islands may well have public health significance. Here again, laboratory model studies should precede field investigations.

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PHASE 4 - FATE AND TRAVEL OF FERTILIZERS, INSECTICIDES AND HERBICIDES

The contamination of natural waters by chemicals used in industry and agriculture is receiving more and more attention as their presence in such waters becomes increasingly evident. The development and use of new compounds has increased six to eight-fold in the last decade. Many of these chemicals are developed for the control of agricultural pests and, consequently, exhibit toxic properties. The quantities used and the methods of application are conducive to water quality problems the seriousness of which is not fully known. A recent report of a President's Advisory Committee indicates the importance given to this problem by public health administrators and other persons in high offices.

In the Hawaiian Islands situation, the potential problem is largely that of the contamination of the basal water by fertilizers, insecticides and herbicides used in agricultural operations and in the landscaping of homes. Item I describes the situation as regards methods of irrigation and the use of these chemicals.

On the Mainland the return flow from irrigation is considered a source of pollution of both ground and surface waters. Fertilizers, insecticides and herbicides are among the major constituents of this return flow. That part of the irrigation water which enters the ground water is suspected of contributing to high nitrate content of some well supplies. Whether or not the insecticides and herbicides find their way in the ground-water aquifers is still not definitely indicated. However, a number of research projects are under way to study the reactions of many of these chemicals in the soils of various areas, as well as their travel in subsurface strata, and many reports are available on the subject.

The conditions in Hawaii, so far as can be determined by present knowledge, are conducive to a potential basal water contamination problem of this type. Whether one exists and whether one should be anticipated for the future is a matter for research to determine.

It is suggested that this project be approached from two directions. First, to determine if the problem exists. For this purpose it is suggested that the carbon-filter technique as used by the Robert A. Taft Sanitary Engineering Center in Cincinnati, and others, be considered as major equipment for the project. (See references.) This technique consists of passing the water to be tested through a tube containing activated carbon which has the ability to absorb organic compounds. Thus, these compounds are concentrated into a small volume of carbon. This equipment can be mounted in a portable installation and moved to a number of selected locations.

The project will also necessitate the use of equipment for carbon extraction and residue analysis. This is a type of equipment that will have considerable use in water research. Dr. Ryckman and his staff at Washington University in St. Louis, and Dr. H. Page Nicholson of the Pesticide Pollution Studies, Public Health Service, Region IV, Atlanta, Georgia can be of considerable help in laying out a project and developing techniques and equipment for this study.

Tests for nitrates, potash and phosphates resulting from the use of fertilizers should be included in this reconnaissance study as well as the identification of insecticides and herbicides.

The selection of locations for these studies is important. It is suggested that initially the carbon filter be installed at a number of existing water supplies on several of the islands. While it is not suspected that these supplies contain contaminants of the type involved in this study, it will be of interest to learn if there are organics of any type and quantity present. The principal locations for the equipment should be in wells (probably shallow but in the basal water) in agricultural areas where various types of soils and rock structures are represented.

The second direction this project should take is a study of the reactions of the fertilizer constituents and the major insecticides and herbicides used on the Islands, in the various soils where this use predominates. For this purpose, lysimeters similar to those used in the recharge studies in California, but adapted to Hawaiian soils, are suggested, at least, for the initial investigations. (See "An Investigation of Sewage Spreading on Five California Soils," Sanitary Engineering Research Laboratory, University of California Technical Bulletin No. 12, I.E.R. Series 37 - June, 1955.)

For field studies, the techniques described in the "Final Report on Investigations of Travel of Pollution" by the Sanitary Engineering Research Laboratory, University of California, may prove adaptable. These facilities consist of well fields and test plots. It is suggested that a well-designed facility of this kind would be of value for a number of types of study and would be a valuable adjunct to a water research program.

The carbon-filter technique will also be of value in this study as a means of concentrating the material and separating and identifying quantitatively the specific substances under investigation. This applies, of course, to the insecticides and herbicides rather than fertilizer constituents. The substances selected should be those commonly in use in the various agricultural areas.

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PHASE 5 - REACTIVITY OF SOILS VS. HEAVY METALS IN BASAL WATER

This is the most questionable of the various phases of the basal water project suggested here. The possibility of a problem due to significant concentrations of heavy metals in the basal water may be remote. Yet, the soils of some areas are known to be exceptionally high in these metals and are said to be "quite reactive." The effects of weathering, high rainfall and irrigation on these metals undoubtedly have been the subject of study by soil scientists. Whether or not it is possible for the metal ions to enter the basal water and to remain in solution in significant amounts has, in the knowledge of the writer, not been determined.

Initially, therefore, this project should consist of an investigation to determine the heavy metal content of basal water samples taken from a number of selected locations. The tests should include those metals which have been found to be present in the soils, such as copper, chromium, iron, manganese, etc. At the same time lysimeters may be used to determine if these metals are leached from the soils, in what quantity and under what conditions.

According to the Public Health Service Drinking Water Standards, concentrations of these metals should not exceed the following limits: Arsenic, 0.01 mg/l; Copper, 1.0 mg/l; Iron, 0.3 mg/l; Manganese, 0.05 mg/l; Chromium, 0.05 mg/l; Lead, 0.05 mg/l; Barium, 1.0 mg/l; and Cadmium, 0.01 mg/l. These values will be of use as guides to the development of test procedures.

PROSPECTUS NO. 2

OCEAN DISPOSAL OF EFFLUENTS

THE PROBLEM

Item I of this report discusses the features of the State of Hawaii which led to the decision that the nearshore waters of the ocean must, for the most part, be the receiving water for sewage and waste effluents. In a report dated Feb. 1960, consultants for the then Hawaii State Planning Office devised an "action program" for the development of "Visitor Destination Areas in Hawaii." Maps of the Islands contained in this report show all of these areas on the ocean shore especially in those locations where there are sand beaches. This, of course, is not surprising because there are few other locations better adapted for recreation and resorts.

Whether or not this particular program is followed, there is no doubt about the need for developing new tourist areas, that these areas will be on the ocean shores, and that the chief asset will be the beach and nearshore waters. This development has already started. It includes state and county parks, private hotels and resorts, and homesites for the supporting population.

These centers of population concentrate the sewage disposal problem in areas where the coastal waters are most valuable and will receive the greatest use. Yet, these same waters must be used for the disposal of the sewage (after treatment).

If there is to be industrial development on the Islands, the location of these industries will be governed by many of the same features as influence the location of population. These industries will also need to use the nearshore waters of the ocean for waste disposal.

It is apparent, therefore, that ocean disposal must be accomplished in a manner which will not interfere with its value for recreation and as a tourist attraction. There are a number of problems involved among which are those of public health, unsightly shore deposits and floating sewage fields and the effects of the wastes on the fish and aquatic resources of these coastal waters. Already several projects are under way to study these problems, as mentioned earlier in this report.

Objectives of Research

Generally stated, the major objectives of this project are to develop fundamental data and information on the physical characteristics of inshore coastal waters of the Islands to permit a scientific evaluation of the factors concerned with the location, design, construction, operation and effect of ocean sewage and waste disposal facilities, including outfall lines and barges. This will involve observations of waves, longshore currents, winds and beach profiles including reefs, at areas along the coasts of the several islands selected on the basis of community development and where resort and industrial development is anticipated.

Also involved as an objective is a study of methods of mixing of the effluents with the higher density sea water to prevent the formation of floating sewage fields or areas of high concentration of contamination.

PHASE I - OCEANOGRAPHIC STUDY

The design of an ocean outfall system depends upon the conditions at the site. There should be strong littoral currents with little movement shoreward. Winds and wave direction are factors as are temperature and salinity gradients. Dilution is limited by the amount of new water brought through the area. The circulation pattern, variation and velocity of currents, and time required to reach shore under various conditions are important to the design and site of the disposal lines.

The fate of effluent released into the marine environment cannot yet be predicted by existing theoretical models. Whether or not the effluent will move directly inshore, offshore or parallel to the coast can only be determined by extensive field work. The degree of success of predicting the path of the effluent will be directly related to the amount and type of field work accomplished.

This type of study is, of course, not without precedent. However, oceanographers are usually more involved with ocean currents and deep water conditions than with specific nearshore factors. These factors may be of greater influence on immediate dispersion and assimilation of effluents than offshore conditions.

The development of a method for the direct observation of movement and dispersion of nearshore waters is said to have greatly simplified this field work. This development utilizes the fluorescent organic pigment, rhodamine B, together with a stable, compact fluorometer. The tracer has been found to be satisfactory with regard to stability, cost and detectability.

A study of diffusion from point sources simulating an outfall is suggested as a part of this project. Whether or not the dye can be used to indicate the pattern of diffusion of sewage and waste effluents is subject to question. The writer feels that this study may require the development of new techniques.

In conjunction with the dye studies, data should be collected regarding the depth of the layer involved in mixing and its movement. Nansen bottles, reversing thermometers, bathythermographs and current meters are available for such studies.

Prior to the construction of a sewage outfall, diffuser, or other structure, a study of the marine geology of the proposed area should be made in order to determine (1) whether bottom topography and foundation conditions make such construction feasible, and (2) whether the addition of the structure will upset a natural equilibrium, thereby causing extreme erosion or deposition. A complete survey of nearshore areas, therefore, should consider in some detail bathymetry, bottom materials and sediment movement, particularly littoral drift. The topography of the shorelines and beaches is not static. The character of the shore, the location of reefs, and the direction and velocity of winds are related to the ocean waves and the direction and magnitude of longshore currents, and should be delineated in each area.

Presumably the reefs which exist along much of the shoreline of the Islands may be used to implement mixing. Channels and openings in these reefs may be areas of high current velocity, both inward and outward. Tides, although of comparatively low magnitude, may have their effects on such currents. The location of the outfall with respect to the reef is certainly important. Trade winds normally predominate on the Islands, but there are often long periods of southerly winds. Studies must extend over such periods.

PHASE 2 - EFFLUENT - SALT-WATER MIXING STUDY

The success of ocean disposal of sewage and waste effluents depends upon immediate and thorough mixing with the salt water at the discharge point. A factor which works against effective mixing is the difference in the density of the two liquids. The lighter effluent rises rapidly to the surface, forms a layer which does not mix readily with the heavier salt water and tends to travel shoreward under the influence of waves and wind.

It is suggested that a study of the mixing of the two liquids in the more turbulent flow of the outfall line is in order. The density of such a mixture will approach nearer to that of the sea water into which it is discharged and should minimize the formation of surface layers of unmixed effluent. This study will involve the determination of physical factors concerned with velocity in the conduit, the admittance of salt water, methods of producing the necessary turbulence, the quantity of salt water required, and the design of necessary structures.

For all practical purposes, fresh water can be used to represent the effluent, and salt solutions of various concentrations to represent the ocean water. The study is adapted to equipment of the hydraulic laboratory type although plastic tubes may be used as the conduits.

One method for injecting the salt solution is by means of an aspirator type of piping where the conduit carrying the fresh water is passed through a tank of salt water simulating the ocean. The design of this equipment should allow for flexibility in pressures applied, size of jets, size of inlet, etc. Both the chloride and density measurements should be used for controls.

Another method suggested is that of direct pressure injection of salt water into a conduit containing flowing fresh water. In this case the study of the turbulence necessary to effect complete mixing is important.

Since the object is to obtain a mixture which will diffuse more rapidly with the ocean water and which will not form layers of low density on the surface, the project should include a study of the diffusion of the various mixtures in ocean water.

This is a hydraulic problem which will require the application of fluid mechanics. The end objectives should be to establish the design criteria for the structure needed and the character of the resultant mixture.

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PROSPECTUS NO. 3

WATER QUALITY VS. FISH AND SHELLFISH

THE FISHERY PROBLEM

The "Report of Industrial Waste Disposal Study Commission of The 28th Legislature of Territory of Hawaii" (Feb., 1955) contains a statement regarding the effects of pollution on fish and marine life. This report states that "the pollution problem as it affects fisheries is most acute and is responsible for the greatest economic loss where it occurs in harbors and bays and other enclosed bodies of water which are or have been sources of live bait for tuna fishing. Such pollution may in turn have a harmful effect on the productivity of our tuna fisheries."

Nehu, the bait fish in question, spends much of its life in the brackish waters. The major areas of concern are Kaneohe Bay, Honolulu Harbor, and Pearl Harbor on Oahu, Kihei Bay on Maui, Hilo and Kawaihae Bays on Hawaii, and Nawiliwili and Port Allen on Kauai. Oil pollution and low dissolved oxygen are said to be largely responsible in the past for the damage done to this fishery. However, it has been suggested that other factors may be involved such as the formation of sludge beds or the effects of toxic insecticides and herbicides which may wash from the adjacent agricultural lands. These substances may not only affect the fish and shellfish in confined areas, but may destroy the aquatic organisms used as food by these fish.

Discussions with the State fishery officials indicate their concern not only for the bait fish of the brackish water areas but for coastal species as well. One of the problems that has not been assessed is the effect of the sugar-mill wastes and bagasse discharged to coastal waters at many locations. The sugar industry feels that the pollution from these sources is limited to such small areas - about 5 acres - of water in the vicinity of the mill discharge that the effect, if any, is of minor significance. Fisheries officials are not sure that this is the case and point to a need for a comprehensive study of the whole water-quality-fishery problem of the coastal areas.

In addition to the marine fishery, there is a fresh-water sports fishery on some of the islands of the State, especially on Kauai. The State Fish and Game Department is attempting to develop this fishery, and trout and other fresh-water species have been planted in some reservoirs and perennial streams. There apparently has been no evidence of damage to this fishery by pollution. Most surface streams are located at higher elevations and above sources of pollution, except perhaps that resulting from runoff of agricultural lands. Again, based on Mainland experience and because of the considerable use of agricultural chemicals in cane and pineapple areas, a study seems to be indicated to assess the potential damage to the fresh-water fishery in those surface streams receiving irrigation return flow. Three research projects are suggested as appropriate.

PHASE 1 - FIELD INVESTIGATION

There is considerable precedent for a type of study which would catalog the aquatic populations in the estuarial and coastal marine waters and the surface fresh waters of the Islands. Such a type of study is undoubtedly required to evaluate any problem that may exist. It is suggested, however, that typical areas for study be carefully selected in order to limit the work involved since a comprehensive survey of all the coast lines of the Islands could develop into a major task.

The estuary and coastal study should consist of the collection, identification and enumeration of the biological life, including fish and shellfish, which exists in areas of suspected and known pollution as compared with those found in clean-water areas of a similar type. This cataloging of biological life should be accompanied by certain physical and chemical tests to establish the differences in the aquatic environment. The tests selected for any particular area will be governed by conditions at that location. Included in most cases will be temperature, salinity, pH and the presence of sludge beds. In some locations, oil may be involved. In others, such as some of those receiving sugar-mill wastes, tests for insecticides and herbicides may be appropriate. The results of these studies should finally be used to evaluate any indicated fishery problem. It should be recognized that this study will have other values in addition to evaluating the pollution-fishery problem.

PHASE 2 - BIOASSAY

It seems to the writer that there is a real need on the part of the fisheries agencies for a method of bioassay which is adapted to use under the conditions which exist on the Islands. Again, there is precedent or, at least, a starting point for such research in the work done at the Robert A. Taft Sanitary Engineering Center at Cincinnati, at Oregon State University, Corvallis, and elsewhere.

The objective of bioassay is to detect unfavorable environmental conditions for desirable aquatic life. Among the environmental factors involved are temperature, low dissolved oxygen and toxicity. Toxicity is the most difficult to detect and bioassay is a major tool for its detection.

There are two types of toxic effects, namely acute and chronic.

Acute effects usually result in "kills" which are so apparent and spectacular that they are given more importance than they warrant in comparison with the results of chronic toxicity. The latter results in a slow, day-by-day effect on the environment which is often difficult to measure and which may be apparent only after long periods, but which may completely destroy desirable aquatic life.

Bioassay methods to date have been designed largely to detect the actute type of toxicity. They consist of a measurement of the short-term lethal effects of the water or waste suspected to be toxic on a selected specimen. The results are expressed in terms of mortality. These bioassay methods are fairly well developed and, so far as their use on the Hawaiian Islands is concerned, studies should largely involve the selection of a type of specimen which will represent the special aquatic fauna. Such a study is desired to provide the tool for acute toxicity investigations, and will be useful to both the fisheries and the pollution control agencies.

Devising a method for bioassay of chronic toxicity is a more difficult and challenging task. However, as previously intimated, such a method is badly needed for the preservation of the fishery in this rapidly-expanding industrial era. It should be designed to detect chronic effects before they are fully exerted. The point of reference will probably be the change in the physical condition of the specimen organisms over long-time exposure rather than its actual destruction. This is an area in need of fundamental research involving a number of disciplines.

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PHASE 3 - SHELLFISH CONTAMINATION

There appears to be a potential for a sizeable oyster industry on the Hawaiian Islands (Item I). Before this industry can be fully developed, however, the problem of contamination must be resolved. The Pearl Harbor area appears to be an excellent reproduction and growing area, but the Harbor waters are far too contaminated to allow the marketing of the oysters grown there. Also, because of the dedicated use of the land and water of the Harbor, there is little, if any, possibility of ever marketing oysters from that location. There is a definite possibility, however, of developing an industry by using the Harbor waters for reproduction and moving the oyster spat, or perhaps the adult, at some stage of growth, to an uncontaminated area for marketing.

There are three conditions of bacteriological contamination recognized by sanitation standards. The first is that of the area from which the oyster can be directly removed for marketing. In this case, the area must not contain more than an MPN of 70. (MPN is defined as the most probable number of B. coli of human origin per 100 ml.)

Second, in those areas where the MPN is from 70 to 700 the oyster must be removed to a clean area for at least three days. The third condition is one involving a grossly contaminated area, above an MPN of 700. The time required for an oyster to clean itself when removed from such an area to an uncontaminated one has not been established. There seems to be little doubt that a year is more than ample and may be far in excess of the time required.

Herein lies the problem regarding which a study appears desirable. If the oyster is to be reproduced in Pearl Harbor and moved to another area for clearing of contamination prior to marketing, what is the best period of growth for such a move? This involves not only the removal of contamination, but methods and costs. In Japan, oysters are grown on wires hung from barges. Would such an arrangement facilitate moving? To what location should they be moved? These questions constitute an excellent subject for an objective research project.

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PROSPECTUS NO. 4

SEWERAGE

THE PROBLEM

Sewage collection, treatment and effluent disposal are and will continue, for some time, to be a major water problem of the State of Hawaii. The dependence on cesspools for sewage disposal has been of such long duration that there is now a considerable backlog of sewer construction. This, the rapid expansion of population on Oahu and the increase in rate of construction over all of the Islands combine to make sewerage the number one problem.

Conventional methods of sewage treatment are, of course, always available, but not all of these methods are adaptable to the physical and econonic conditions of specific areas. The selection of the method of treatment best adapted to these conditions is often a subject of uncertainty. In many cases the selection is governed almost entirely by costs and ability to pay. This, of course, is not a proper criterion, but it is a fact which must be reckoned with.

Effective, low-cost methods of treatment are, therefore, in demand and it should be the objective of research in this field to provide for lower cost processes and facilities to meet the needs without sacrificing efficiencies. This is of utmost importance in the Hawaiian situation due to the financial burden which must be carried by fewer than usual people.

PHASE 1 - SEWAGE DISPOSAL BY IRRIGATION

Irrigation is one of the least expensive and most effective methods of sewage treatment provided conditions favorable for its use exist or can be met. In fact, this is a form of water reclamation which may have values other than that of sewage treatment. For this reason, and in spite of the fact that land on the Islands may be high-priced, especially in the vicinity of populated areas, and that the basal water table underlies much of this land, a study of irrigation as a means of sewage disposal is considered appropriate. It may not have its application in large communities, but can be the answer for some small communities and resort areas.

Also, there are numerous small communities so located as to preclude the disposal of treatment plant effluent into the ocean. In these cases, disposal into seepage pits seems to be necessary and, in fact, is the only recourse left. This is almost a direct introduction of the effluent into the ground water. Disposing of the effluent by irrigation, while the water may eventually find its way into the same ground-water strata, has the advantage of filtration through soil, if research indicates that this is an advantage.

The disposal of sewage, industrial wastes and treatment plant effluents by irrigation on land is a practice almost as old as the use of water as a carrier of human and trade wastes. In spite of the age of this practice, there are as yet no dependable criteria on which to base the engineering design of facilities for this purpose. Since land disposal is considered to be a legitimate means for the treatment of wastes and effluents, it is essential that criteria be developed which will not only guide the design of the facility, but will insure the maximum use of the land area and the protection of ground water.

The practice consists of spreading by spraying, flooding or otherwise, sewage or plant effluent which contains bacteria and organic substances onto land which may be either fallow or plant-covered. In theory, the bacteria and organics are strained from the carrying water or are oxidized or otherwise decomposed by soil bacteria before the water percolates into the ground-water strata or seeps into surface waterways. If the process works according to theory, the result is the complete treatment of the sewage.

The general objective of this study is to develop criteria as guides for the use of irrigation as a means of sewage treatment or treatment plant effluent disposal. Since the use of this process will depend upon the effect on the ground water, the results of Phase 3, Prospectus No. 1, the fate and travel of bacteria and viruses in soils and rock formations, are essential to this study. If these results are not available, the study suggested in Phase 3 should become a part of this project.

Irrigation may be applied to the treatment of raw sewage (following screening and grit removal), to primary settling plant effluent or to the effluent from secondary processes. This project should be located, therefore, where the raw materials are available. Among the items that should be included in the study are:

1. A determination of the combination of soil and plant cover best adapted for the destruction of the organics of the sewage or effluent and the assimilation of the water.

2. The effects of continuous application on the characteristics of the soils, such as changes in soil texture, permeability, organic content, etc.

3. The maximum rates of application for various soils and crops.

4. The maximum loading of organic matter.

5. The relation of climatic conditions - temperature and rainfall.

6. The value of continuous cultivation as opposed to cropping.

7. The extent of travel of contamination - bacterial and viral.

8. The fate and travel of nutrients and organics in the soils.

This study should establish the best combination of soil, plants, methods of application, rates of application, loadings and other guidelines which will aid in the selection of sites and the design of facilities and methods of operation. In addition to establishing these criteria, the study should determine the effects on the ground water.

It is suggested that initial investigations be made in pilot installations and that these be followed by the use of test plots equipped with underdrains or test holes for sampling of seepage water. The plots should be both cultivated and cropped. Crops should be selected on the basis of their eventual use as well as their adaptability to large applications of water. Sugar cane and alfalfa may be the most promising.

Irrigation, if properly employed, is an effective means of waste treatment. In far too many cases it has not fulfilled expectations, usually because it was expected to work under every and all conditions. In a way, this method parallels the use of lagoons as a means of waste treatment. The latter has only recently received the technical considerations needed to become an efficient process. Irrigation provides temporary storage of the liquid wastes in soil pores rather than in ponds; breakdown of organics is accomplished by soil microbiota rather than algae; and nutrients are utilized by land plants - grass, crops, brush or trees - rather than aquatic plants.

Properly employed, irrigation can provide almost complete treatment. The process may be less expensive than other methods, depending upon land values and location with reference to the waste source. There may even be a substantial return from increased crop or forage production.

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PHASE 2 - SEWAGE LAGOONS

Again, recognizing the high value of land, the permeability of the soil, and the underlying water table as factors against the use of lagoons for the treatment of sewage, it is suggested that in spite of those factors a study of this method of disposal is appropriate. Since this is a comparatively inexpensive and effective method, there may be more uses made of lagoons for this purpose than anticipated. This is especially true if, through research, the effects of some of the opposing features can be minimized or reduced.

Studies on the Mainland and in Australia have established criteria of lagoon design and operation for conditions existing in these areas. Some of these criteria may be adaptable to conditions on the Hawaiian Islands while others may not.

There are two areas of research suggested, both of which have not been completely resolved by previous studies and both of which will influence the application of lagoons in Hawaii.

Sealing or Compaction

The first study is that of methods for compacting or sealing of the lagoon dikes and bottom to prevent seepage. Sealing is important from at least two standpoints. First, it is necessary to maintain a full lagoon if biological action is to develop and progress properly. Due to the high rate of infiltration of most Hawaiian soils, methods of compaction normally used may not be effective, except perhaps where the lagoons are located in cap-rock areas. The second reason for effective sealing is to avoid contamination of basal water.

The Missouri Basin Engineering Health Council in 1959 developed criteria for the design, construction and operation of sewage lagoons as part of what has become known as the "Ten-States Standards." This report stresses the importance of a tight lagoon bottom and dikes. Compaction is "usually accomplished through judicious use of conventional earth-moving equipment." The use of bentonite, asphaltic coating, clay blanket and other sealing material is considered only in case of special situations. It is suggested that situations on the Islands may all come under this classification. Even the use of polyethylene films under a thin cover of soil may be required. Sealing is an important item in connection with lagoon design and is a factor affecting the cost.

Solar Energy and Temperature

Sunlight is a major factor in the operation of an aerobic sewage lagoon as are air and water temperature. Much of the research regarding lagoons on the Mainland has been done under sun and temperature conditions much less favorable than apparently exist on the Hawaiian Islands. Design criteria recommended by the previously-mentioned "Ten States" are based on climatic conditions of the Missouri Basin. Higher loadings may well be in order under Island conditions.

It is suggested that a pilot lagoon, located in a typical area where sewage is available in excess quantity, be used for this study. The techniques used in other research of sewage lagoons can largely be applied to this study.

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PHASE 3 - COMBINED SEWAGE AND INDUSTRIAL WASTES

There are instances where some of the major industries have a possible access to a community sewerage system. Whether or not this privilege is given the industry depends in part, at least, on the effects which these wastes may have on the collection system and treatment processes. Two types of wastes which are subject to question in the Hawaiian situation are those from cane-sugar mills and pineapple canneries. Since these are organic wastes, they should respond to the biological processes used for the treatment of sewage. The questions, then, are: (1) What amount of pretreatment is required to prevent accumulation in the sewer system and on screens, grit collection and settling units of the treatment plant? This is especially a question applied to sugar-mill wastes due to the exceptionally large load of suspended matter. (2) What is the nature and magnitude of the organic load imposed on both the anaerobic and aerobic biological processes? These wastes may not be ideal from the standpoint of nutrients for the biological processes. (3) Is there a limit in the proportion of waste to sewage as regards the efficiency of the treatment processes? (4) What proportion of the costs should theoretically be imposed on the industry?

This is the type of research which lends itself to pilot plant studies. It is suggested that the pilot installation be portable and should simulate the conventional sewage treatment processes. Plant design and study techniques are available in the literature.

An important consideration not previously mentioned is the effect of the waste on the efficiency and cost of disinfection by chlorine. An estimate of this effect can be obtained by a laboratory study.

The importance of this study will depend upon the anticipated demand for the use of community sewerage systems by industry. The State Department of Health is in a position to judge this anticipated demand.

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PHASE 4 - SEWERAGE PLANNING

The discussion which follows certainly does not involve research in the usual sense of the word. The suggestion for a sewerage plan is made here since, in the opinion of the writer, it is desirable for an orderly and effective solution of the State's sewerage problems. It is not emphasized because there are other factors involved besides desirability which must be considered before such a project is initiated.

The Hawaiian situation, created by the absence of municipal government and the over-all responsibility of the County, would seem to lend itself to such a planning procedure. While plans need to be flexible, it appears to be possible, through the same process used for planning of water supplies, to plan sewage collection, treatment and disposal in the same general way. This planning would take into account population and economic forecasts, land-use forecasts or plans, water use, disposal sites and receiving waters, physical layout, treatment requirements, etc. It is not proposed, however, that this plan involve engineering design either of sewer systems or treatment plants. Rather, the purpose would be to locate the areas where sewerage service is anticipated, the general limits of those areas, a forecast of the population to be served, plant sites, etc. This plan should be such as to act as a general guide to the County and State agencies, consulting engineers and others and should establish somewhat of a schedule of activities in keeping with the anticipated needs. It should eliminate uncertainties since all agencies involved would be in agreement and all proceeding in an orderly manner. Of course, this is the theoretical advantage of planning which is not always attained in full.

Much of the information on which to base such a plan is already available. Involved are: (1) Economic forecasts of population and areas of development. This should include some indication of the anticipated ability to pay. (2) Surveys of the receiving waters to guide treatment requirements as well as selection of the points of discharge. Oceanographic and basal water studies previously discussed should furnish some of the information required. (3) In most cases soil conditions, percolation rates, the source of water supply, rainfall data, and availability and value of land are essential types of information.

It is suggested that this may best serve as a joint County and State project since the State Department of Health has approval responsibilities and is the contact agency for Public Health Service construction grants and the County has responsibility for design, construction and operation.

PROSPECTUS NO. 5

INDUSTRIAL WASTE DISPOSAL

THE PROBLEM

The major industrial waste disposal problems of the State of Hawaii are those from the processing of cane sugar and pineapple and the refining of oil. Smaller industries which may require some change in disposal methods in the future are slaughterhouses and milk processing plants. These presently dispose of wastes into cesspools unless they have access to a community sewer system. Information regarding the Hawaiian industries and their present methods of waste disposal is outlined in Item I of this report. Item II contains statements regarding the waste problems of these industries as viewed by the writer.

PHASE 1 - CANE-SUGAR MILL WASTE

As previously indicated, a major waste disposal problem of the Islands' cane-sugar industry is caused by the type of mechanical harvesting equipment in use. Manual harvesting, which consists of cutting the cane top and bottom and stripping the leaves, is no longer in general use either on the Mainland or the Islands. By this method the amount of trash hauled to the mill was small. However, the cost of labor has made necessary the development of mechanical harvesting equipment. This type of mechanical equipment used in the southern states of the Mainland fairly well simulates the manual operation. This equipment cuts the cane free of the ground and tops it. The amount of trash hauled to the mill when this equipment is used is about 5 per cent of the weight of the cane.

The method employed by Hawaiian mills, however, consists of pulling the cane from the soil and transporting the cane, trash, roots, and adhering soil and rock to the mill. The amount of extraneous material in this case, especially when the soil is wet, is up to 50 per cent of the weight of the cane. One mill on the Islands is said to collect and haul away 40 ten-ton truck loads of this material per day. In addition to this dirt and trash, this particular mill produces over 500 tons of bagasse per day. These figures indicate the magnitude of the solid waste problems of the mills.

The problem is magnified by the four million gallons of water used daily, much of which is required to wash the mud and debris from the cane and to transport this material away from the mill. To effectively separate the solid matter from the water is a difficult and expensive operation.

The most logical approach to a solution of this problem appears to be the development and use of a type of harvesting or cleaning equipment which will leave most of the soil and trash in the fields. The industry appears to be taking some action in this direction, largely from the point of view of soil conservation and operation costs.

Although improved harvesting equipment will greatly reduce the amount of solid material now discharged in these wastes, there still will remain a substantial waste-disposal problem. (This is evidenced by the waste problems of the cane-sugar industry in Mainland states.) Some mills have installed hydroseparators for the removal of solids, but the effluent from these separators is from all appearances still very high in potential polluting substances.

It would seem that the research should be aimed at the ultimate use of all of the waste water for irrigation either in cane fields or for other crops (alfalfa, fruit and nut orchards, etc.), depending upon the situation at the mill site. The problem, therefore, is largely that of preparing the waste for irrigation and determining any effects on the crops where it is used. The amount of preparation will again depend upon the situation at the mill location. For instance, if pumping is required, a much more efficient removal of solids will be necessary than if the waste can flow to the land by gravity.

Waste Survey

The first step in this suggested study is an adequate waste survey of several typical mills to delineate and assess the nature and magnitude of the waste-treatment problem. Studies made in other areas will guide the plan for such a survey which apparently has not been made in the mills of the Islands. The survey should involve a separate analysis of washer effluent, process water and total waste. Among the determinations should be volume of waste, suspended and settleable solids, $_pH$, BOD and a bioassay for toxicity. The latter is recommended since, if insecticides and especially herbicides from the soil and vegetation are contained in the waste water, they may affect the crops which are to be irrigated. The results should be related to production in order to be applicable to other mills.

Bagasse Research

One of the major research projects required is that of the utilization of bagasse. This matter has been and is the subject of considerable research by the industry and other interested entities. However, because of the large amount of bagasse produced, it is doubtful if any one development, such as the composition board now produced at Hilo, will completely utilize this material. This is an area for developmental research aimed at the production of by-products. It is understood that the Hawaiian Sugar Planters' Association has such a study under way but, because of the magnitude of the problem, there is room for other ideas and researchers.

Liquid Waste Research

The principal requirement in preparing the liquid wastes for irrigation is that of effective suspended solids removal. Several items are suggested for study, based on experiences in other industries.

The first of these has already been mentioned several times in this report and involved a different type of harvesting equipment. In lieu of or in addition to this equipment, it is suggested that a study be made of dry-cleaning equipment as a preliminary method of removing the major portion of the soil. Perhaps the shaker method employed by beet-sugar factories to remove adhering soil can be adapted for this purpose. If such equipment were portable and installed in the field, some of the cost of transporting this material could be eliminated, especially if it were designed to work under wet weather as well as dry-weather conditions.

After the water has passed through the mill it contains a considerable amount of trash and bagasse. Consideration of improved screens and screen installations to remove this material prior to settling appears to be in order.

The next step is that of settling out the major portion of the suspended soil and organic particles. It is suggested that mechanically-operated grit chambers for the removal of the heavier particles of sand, soil and rock from the wash water be investigated. Such structures might constitute a less expensive method of solids removal than the presently-used hydroseparators. They have been used in connection with an endless belt conveyor for the treatment of beet-sugar waste. One such installation removed an average of 11 cubic yards of soil per million gallons of waste and loaded it directly in trucks or piled it for subsequent hauling. In this case, a series of straight-line grit channels, with mechanical scrapers and a rate of flow of about one foot per second removed most of the settleable material. Equipment manufacturers in many cases have supplied equipment for such studies.

In some cases, the effluent from the settling process can be used directly for irrigation. In most cases, however, especially where the land to be irrigated is some distance from the mill and pumping is required, it is necessary to provide storage and a further removal of suspended material. Lagoons are in use in some mills for this purpose. However, these lagoons have not been designed with any criteria in mind. It is suggested that if this waste is to be used consistently and effectively for irrigation, a study is required to determine the desired characteristics. Such items are capacity required for effective removal of suspended matter without encountering putrefaction, the effective depth considering the capacity needed for settled material, the effect of decomposition in the bottom accumulation, the best design to minimize the cleaning operation, cleaning equipment, and the best types of pumps or other irrigation water equipment based on characteristics of lagoon effluent. Finally, a decision should be made regarding any possible effects of residual herbicides and weedicides on the crops to be irrigated. The latter may be far-fetched, but can only be certain after the results of a study are available.

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PHASE 2 - PINEAPPLE-CANNING WASTES

The Pineapple Research Institute of Hawaii has an active research program directed to improved methods and products. The studies of this Institute as regards wastes from the canning operations are limited to the utilization or development of by-products. This program, however, has greatly reduced the magnitude of the waste-disposal problem in those canneries where by-product manufacture is practiced. Liquid-waste research has, in the past, however, been left to the National Canners' Association Laboratory in Berkeley, California.

The product is fairly clean when it reaches the cannery. In most plants the pulp is dried, ground and supplemented for use as cattle feed. In other cases it is dried for composting.

The principal sources of waste are the wash waters from the raw product and from the fruit cylinders. Cooling water is sometimes returned to wash the fruit. Non-potable juices may be clarified by ion-exchange, and used. Some attempt has been made to produce wines or other fermentation products from these juices, but since they are not high in sugars, these attempts have not been very successful.

For the most part, treatment on the Islands consists of screening and lagooning. These lagoons, however, are designed largely on the basis of hydraulic capacity without sufficient regard to loading criteria; consequently, they are not as effective as they should be and, in at least one case, are the source of objectionable odors.

Suggested Research

There appears to be a need for a study of screens and their installation. Screens observed were not as efficient as they should have been largely due to leakage around the screen. The National Canners' Association has had considerable experience with screens and will be able to advise regarding this study.

The second suggestion for study is that of developing design criteria for lagoons and determining the need for preliminary or supplemental oxidation or the use of nutrients. Such studies should be conducted in pilot lagoons, rather than in full-scale installations, which will allow flexibility and is less costly. Techniques developed for other lagoon studies are available for use in this case and will not be discussed here.

In connection with the above study, it is suggested that investigations be made on a pilot-plant scale of both short and long-period pre-aeration as a preliminary means of reducing the oxygen demand and the formation of odor-producing compounds. It has been found in treating other industrial organic wastes that substantial reductions in the oxygen demand result from short-period aeration (4 to 6 hours) without the use of an activated sludge. At the same time there is a certain degree of agglomeration of what may be protein compounds. A preliminary aeration period of this magnitude may improve lagoon treatment and reduce the size of lagoons required.

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PROSPECTUS NO. 6

SALT-WATER CONVERSION

THE PROBLEM

Within the last few years considerable emphasis has been placed on the growing demands for water. Concern regarding the adequacy of the Nation's future water supply has led to Federal government support of a substantial salt-water conversion research program. Numerous projects are under way, some of which are in what is considered full production and reports of which may be found in the literature.

It has been said that water is not scarce, but is often out-of-place. Some areas have supply in excess of the needs, while others are in short supply. This is certainly the situation in the Hawaiian Islands and in many other islands of the South Pacific. Many of these islands and atolls are uninhabitable, or habitation is limited because of lack of fresh water, although completely surrounded by the waters of the ocean. Even on those islands having high rates of precipitation at the higher elevations, there are large areas, mostly along the leeward sea coast, where rainfall is low and ground water is brackish or costly to develop. For example, the basal water is brackish on most of the Island of Naiiau, almost the entire western half of Molokai, the entire coast line of Lanai, all of Kahoolawe, and the south coast of Maui and much of the west coast of Hawaii for a considerable distance inland.

Many of these areas depend upon roof drainage for domestic water. Others are served by long pipelines from well supplies developed at higher elevations. While the latter are apparently filling a need for service to communities and subdivisions, they do not serve a major portion of the area, especially the rural areas.

SOLAR DISTILLATION

Salt-water conversion does not always compare favorably as regards cost where a competitive source is available. This situation may not exist in many of the islands referred to above since, in some cases, there is no competitive source and, in others, the water must be hauled or piped for long distances. Cost, of course, is an important factor, but not necessarily one involved in this research.

The other factor which is pertinent to the South Pacific archipelago and the Hawaiian situation is the almost ever-present sunshine and the warm climate. Under these conditions a great resource of solar energy must be available. This is free energy. Such a situation makes salt-water conversion by solar distillation attractive, and interest has been indicated in a research study of the subject.

An experimental solar-distillation unit is under test at the Office of Saline Water, Sea-Water Conversion Research Station at Daytona Beach, Florida. The unit consists of a shallow basin, painted black and covered with a glass roof on the underside of which the distilled water is condensed and collected. This unit is capable of producing one gallon of water per day for each eight feet of salt-water surface. Thus, on the basis of these tests, an area 20 x 40 feet is required for production of 100 gallons of fresh water per day.

Objectives

The objective of a project of this kind in this area may not be that of producing water in large quantities. It is suggested that a project with the objective of providing water for a single household or small group of people may be of more practical value as regards the actual needs for the area in question. As previously stated, in some areas of the Hawaiian Islands households must depend upon roof drainage as a source of water. Storage is limited and, consequently, during periods of drought water is non-existent or in very short supply and of poor quality. While all such houses cannot be supplied by sea-water conversion, many could and others might be located with this factor in mind. In fact, wells into the brackish basal water might be used to supply the saline water in some cases.

Also, it does not necessarily follow that the "greenhouse"-type unit under test at Daytona Beach is the only possible type of solar-energy unit. The ingenuity of the researcher may result in a type still better adapted to the objectives of this project.

This is truly a water quality research project since it involves a change in the quality of ocean or brackish water to allow its use for domestic and perhaps industrial and agricultural uses. It is suggested here because it seems to have a practical application in areas in and adjacent to the Hawaiian Islands.

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PROSPECTUS NO. 7

FIELD AND LABORATORY METHODS

THE PROBLEM

The study of the quality of the natural waters is becoming more and more complicated. Increasing numbers of chemicals, both inorganic and organic and mostly of complex structure, are finding uses which conduce to their presence in these natural waters. Many of these chemicals are damaging to water uses even in minute concentrations. The production of these substances has been so rapid that methods for their detection and measurement have not kept pace with the problems they appear to be creating. Hense, the principal deterrent to water-quality studies and research is this lack of field and laboratory methods which are specific and quantitative.

This prospectus will not list or mention all of the needs in this area, but will discuss some of the techniques which seem to have an application to the problems of Hawaii. No effort will be made to outline the research procedures in detail since this is one of the objectives of the research.

PHASE 1 - ORGANICS

The development of new techniques and instruments for analytical analysis has progressed rapidly during recent years. Among these instruments and techniques which have an application to organic pollutants of water is gas chromatography. The use of this means of identifying and measuring organics is the subject of a number of studies, but there is still much to be done in applying it to actual field conditions where many interfering substances are involved.

Since the substances under consideration are often significant in minute quantities, the collection of large samples and the concentrating of the substances for testing are of equal importance to the analysis. Carbon filters are in use for these purposes, but there is still room for improvement of this technique. There is always the question of efficiency when a carbon filter is used in the field. There is a difference in carbons, in rate of flow through the filter, cross-circuiting within the filter tube, the selectivity of the carbon, and the percentage of the organic adsorbed.

Research on the analyses of water for organics should include the entire procedure from sampling, concentrating, extraction, separation, identification and measurement, if the results are to be usable. This does not necessarily mean, however, that all parts of the study be carried out in sequence.

The objectives of the study should include:

1. Improvements in sampling techniques in both fresh and brackish waters.

2. Developing and adapting analytic procedures for the identification and quantitative measurement of organic pollutants in water.

3. Improvements in the use of gas chromatography or other techniques for this purpose.

Reference is made to the excellent work of the Robert A. Taft Sanitary Engineering Center, the Engineering Department at Washington University at St. Louis, and other laboratories, as a background for these studies.

PHASE 2 - HEAVY METALS

As previously indicated, the soils in many areas of the Hawaiian Islands are high in heavy metal content. The question has been raised regarding the presence of such metals in the ground waters. Concentrations in the basal water may be minute, yet they may be significant.

The primary objective of the suggested research should be to develop or simplify techniques of heavy metal analysis in the minute concentrations involved and to adapt these techniques to water-quality studies. The research should provide methods for concentrating the metal ions to levels at which they can be readily and accurately measured. Perhaps ion-exchange techniques may show promise in this connection.

Also required are methods of separating the test ions from the higher concentrations of other inorganic and organic substances which interfere with their measurement. Here again, sampling, concentrating, separating and measurement constitute an over-all project.

PHASE 3 - SOILS

Physical and chemical reactions in soils and soil water and their measurement have a direct application to research on ground-water quality. Prospectus No. 1 suggested studies of the fate and travel of bacteria, viruses, insecticides, herbicides, metals, etc., in soils and soil water as a means of predicting basal water quality. Methods of soil testing are involved in these studies.

While this is outside the writer's field, it is understood that there is a need for improved methods for measuring the adsorptive, desorptive, and exchange capacity of soils. This is apparently a project for the soil scientist. However, the viewpoint of the ground-water investigator should be introduced into these studies.

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